UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION III
1650 Arch Street
Philadelphia, Pennsylvania 19103-2029

RECEIVED
FEB 5
DEQ - WATER

Mr. Larry Lawson
Virginia Department of Environmental Quality
629 Main Street
Richmond, VA 23219

Re: Big Otter River TMDLs, Bedford and Campbell Counties

Dear Mr. Lawson:

The Environmental Protection Agency (EPA) Region III, is pleased to approve the Big Otter River TMDLs. These TMDLs were submitted for EPA review on January 04, 2001. The TMDLs for Machine Creek, Elk Creek, Sheep Creek, Little Otter River, and Big Otter River were established and submitted in accordance with section 303 (d)(1)(c) and (2) of the Clean Water Act. These TMDLs were established to address an impairment of water quality as identified in Virginia's 1998 Section 303 (d) list. Virginia identified the impairment for these water quality-limited segments within the Big Otter River watershed based on exceedances of the fecal coliform water quality standard.

In accordance with Federal Regulations in 40 CFR §130.7, a TMDL must be designed to meet water quality standards, and (1) include, as appropriate wasteload allocations (WLAs) for point sources and load allocations (LAs) for nonpoint sources, (2) consider the impacts of background pollutant contributions, (3) take critical stream conditions into account (the conditions when water quality is most likely to be violated), (4) consider seasonal variations, (5) include a margin of safety (which accounts for uncertainties in the relationship between pollutant loads and instream water quality), and be subject to public participation. The enclosure to this letter describes how the TMDLs for Machine Creek, Elk Creek, Sheep Creek, Little Otter River, and Big Otter River satisfy each of these requirements.

Following the approval of these TMDLs, Virginia shall incorporate them into the Water Quality Management Plan pursuant to 40 CFR § 130.7(d)(2). As you know, any new or revised National Pollutant Discharge Eliminations Systems (NPDES) permit must be consistent with the TMDLs Waste Load Allocation pursuant to 40 CFR §122.44 (d)(1)(vii)(B). Please submit all such permits to EPA for review as per EPA's letter dated October 1, 1998. Please feel free to contact Thomas Henry at 215-814-5752, if you have any questions or comments.

Sincerely,

Rebecca Hanmer, Director
Water Protection Division

Enclosure

Decision Rationale

**Total Maximum Daily Load of
Fecal Coliform for Big Otter River Watershed**

I. Introduction

This document will set forth the Environmental Protection Agency's (EPA) rationale for approving the Total Maximum Daily Load (TMDL) of Fecal Coliform for the Big Otter River Watershed submitted for final Agency review on January 04, 2001 Our rationale is based on the TMDL submittal document to determine if the TMDL meets the following 8 regulatory conditions pursuant to 40 CFR §130.

1. The TMDLs are designed to implement applicable water quality standards.
2. The TMDLs include a total allowable load as well as individual waste load allocations and load allocations.
3. The TMDLs consider the impacts of background pollutant contributions.
4. The TMDLs consider critical environmental conditions.
5. The TMDLs consider seasonal environmental variations.
6. The TMDLs include a margin of safety.
7. The TMDLs have been subject to public participation.
8. There is reasonable assurance that the TMDLs can be met.

II. Background

Located in Bedford and Campbell Counties, the overall Big Otter watershed is approximately 388 square miles. The TMDL was developed for the Big Otter River and four of its tributaries. Sheep Creek, Elk Creek, Machine Creek, and the Little Otter River were the four impaired tributaries of the Big Otter river. The TMDL addresses 14.75 stream miles of the Big Otter River from 0.5 miles downstream of the Route 682 Bridge to its confluence with the Roanoke River. The impaired segment of Sheep Creek is 7.33 miles and runs from route 614 to its confluence with Stony Creek. The impaired segment of Elk Creek is 7.48 miles and runs from the Route 643 Bridge to its confluence with the Big Otter. The listed segment of Machine Creek is 20.00 miles and flows from the intersection of Routes 24 & 732 to its confluence with the Little Otter River. 27.22 miles of the Little Otter River is listed as well, stretching from Route 680, to two miles upstream of the Route 460 Bridge. Forest is the major land use in the watershed and makes up roughly 59.0% of the land (this includes three unlisted subwatersheds of the Big Otter (North Otter Creek, Flat Creek, and Buffalo Creek).

In response to Section 303 (d) of the Clean Water Act (CWA), the Virginia Department of Environmental Quality (VADEQ) listed segments of the Big Otter River, Little Otter River, Machine Creek, Sheep Creek, and Elk Creek as being impaired by elevated levels of fecal coliform. These streams were listed for violations of Virginia's fecal coliform bacteria standard for primary contact. Fecal Coliform is a bacterium which can be found within the intestinal tract of all warm blooded animals. Therefore, fecal coliform can be found in the fecal wastes of warm blooded animals. Fecal coliform in itself is not a pathogenic organism. However, fecal coliform indicates the presences of fecal wastes and the potential for the existence of other pathogenic bacteria. The higher concentrations of fecal coliform indicate the elevated likelihood of increased pathogenic organisms.

EPA has been encouraging the States to use e-coli and enterococci as the indicator species instead of fecal coliform. A better correlation has been drawn between the concentrations of e-coli (and enterococci) and the incidence of gastrointestinal illness. The Commonwealth is pursuing changing the standard from fecal coliform to e-coli.

Virginia designates all of its waters for primary contact, therefore all waters must meet the current fecal standard for primary contact. Virginia's standard is to apply to all streams designated as primary contact for all flows. Through the development of this and other similar TMDLs it was discovered that natural conditions (wildlife contributions to the streams) were causing violations of the standard during low flows. Thus many of Virginia's TMDLs have called for some reduction in the amount of wildlife contributions to the stream. EPA believes that a significant reduction in wildlife is not practical and will not be necessary due to implementation discussion below.

A phased implementation plan will be developed for all streams in which the TMDL calls for reductions in wildlife. The first phase of the implementation will reduce all sources of fecal coliform to the stream other than wildlife. In phase 2, which can occur concurrently to phase 1, the Commonwealth will consider addressing its standards to accommodate this natural loading condition. During phase 2, the Commonwealth has indicated that it will evaluate the following items in relation to the standard. 1) The possibility of placing a minimum flow requirement upon the bacteriological standard. As a result, the standard may not apply to flows below the minimum (possibly 7Q10). This application of the standard is applied in many States. 2) May develop a Use Attainability Analysis (UAA) for streams with wildlife reductions which are not used for frequent bathing. Depending upon the result of that UAA, it is possible that these streams could be designated primary contact infrequent bathing. 3) The Commonwealth will also investigate incorporating a natural background condition for the bacteriological indicator.

After the completion of phase 1 of the implementation plan the Commonwealth will monitor to determine if the wildlife reductions are actually necessary, as the violation rate associated with the wildlife loading may be smaller than the percent error of the model. In phase 3, the Commonwealth will investigate the sampling data to determine if further load reductions are needed in order for these waters to attain standards. If the load reductions and/or the new application of standards allow the stream to attain standards, then no additional work is warranted. However, if standards are still not being attained after the implementation of phases 1 and 2 further work and reductions will be warranted.

The Big Otter River identified as watershed VAW-L28R, was given a high priority for TMDL development. Section 303 (d) of the Clean Water Act and its implementing regulations require a TMDL to be developed for those waterbodies identified as impaired by the State where technology-based and other controls do not provide for the attainment of Water Quality

Standards. The TMDL submitted by Virginia is designed to determine the acceptable load of fecal coliform which can be delivered to the Big Otter River and its impaired tributaries (Elk Creek, Machine Creek, Little Otter River, and Sheep Creek), as demonstrated by the Hydrologic Simulation Program Fortran (HSPF)[1], in order to ensure that the water quality standard is attained and maintained. HSPF is considered an appropriate model to analyze this watershed because of its dynamic ability to simulate both watershed loading and receiving water quality over a wide range of conditions.

The TMDL analysis allocates the application/deposition of fecal coliform to land based and instream sources. For land based sources the HSPF model accounts for the buildup and washoff of pollutants from these areas. Buildup (accumulation) refers to all of the complex spectrum of dry-weather processes that deposit or remove pollutants between storms.[2] Washoff is the removal of fecal coliform which occurs as a result of runoff associated with storm events. These two processes allow the HSPF model to determine the amount of fecal coliform which is reaching the stream from land based sources. Point sources and wastes deposited directly to the stream were treated as direct deposits. These wastes do not need a transport mechanism to reach the stream. The allocation plan calls for the reduction in fecal coliform wastes delivered by both point and nonpoint sources. Tables 1a-f document the annual fecal coliform loading (cfu/year).

Table #1a summarizes the specific elements of the TMDL for Sheep Creek.

Watershed	Waste Load Allocation (cfu/yr)	Load Allocation (cfu/yr)	Margin of Safety [a] (cfu/yr)	TMDL (cfu/yr)
Sheep Creek	$\leq 0.1 \times 10^{12}$	1695.2×10^{12}	89.2×10^{12}	$1{,}784.4 \times 10^{12}$

[a] Five percent of TMDL

Table #1b summarizes the specific elements of the TMDL for Elk Creek

Watershed	Waste Load Allocation (cfu/yr)	Load Allocation (cfu/yr)	Margin of Safety [a] (cfu/yr)	TMDL (cfu/yr)
Elk Creek	$< 0.1 \times 10^{12}$	2421.6×10^{12}	127.5×10^{12}	2549.1×10^{12}

[a] Five Percent of TMDL

Table #1c summarizes the specific elements of the TMDL for Machine Creek

Watershed	Waste Load Allocation (cfu/yr)	Load Allocation (cfu/yr)	Margin of Safety [a] (cfu/yr)	TMDL (cfu/yr)

[1]Bicknell, B.R., J.C. Imhoff, J.L. Little, and R.C. Johanson. 1993. Hydrologic Simulation Program-FORTRAN (HSPF): User's Manual for release 10.0. EPA 600/3-84-066. U.S. Environmental Protection Agency, Environmental Research Laboratory, Athens, GA.
[2]CH2MHILL, 2000. Fecal Coliform TMDL Development for Cedar, Hall, Byers, and Hutton Creeks Virginia,

Machine Creek	0.12×10^{12}	414.6×10^{12}	21.8×10^{12}	436.5×10^{12}

a Five percent of the TMDL

Table #1d summarizes the specific elements of the TMDL for Little Otter

Watershed	Waste Load Allocation (cfu/yr)	Load Allocation (cfu/yr)	Margin of Safety [a] (cfu/yr)	TMDL (cfu/yr)
Little Otter	5.65×10^{12}	$1{,}377.7 \times 10^{12}$	72.8×10^{12}	1456.15×10^{12}

a Five percent of the TMDL

Table #1e summarizes the specific elements of the TMDL for the impaired segment of the Big Otter River

Watershed	Waste Load (cfu/yr)	Load Allocation [a] (cfu/yr)	Margin of Safety [b] (cfu/yr)	TMDL (cfu/yr)
Big Otter	$< 0.1 \times 10^{12}$	$1{,}138.1 \times 10^{12}$	59.9×10^{12}	$1{,}198.0 \times 10^{12}$

a Includes upstream inflow from two unlisted tributaries (Buffalo Creek and Flat Creek).
b Five percent of the TMDL

The lower Big Otter River was modeled as receiving a fecal coliform load from all of its subwatersheds, as well as the loading from the impaired segment (lower Big Otter River) itself. The loads from both the impaired and unimpaired watersheds were modeled as if they were a point source discharging a load to this impaired segment. Therefore, the TMDL report has a WLA and LA for the Big Otter River as a stand alone segment. However, in reality the Big Otter was modeled as though it was receiving a load from all of the impaired and unimpaired watersheds. Therefore, EPA believes that the TMDL equation for the lower Big Otter should incorporate all of the loads going to the impaired segment. Table 1f documents the total loading to the lower Big Otter.

Table #1f summarizes the loading to the Lower Big Otter from the segment itself and all other segments.

Watershed	Waste Load (cfu/yr)	Load Allocation (cfu/yr)	Margin of Safety (cfu/yr)	TMDL (cfu/yr)
Big Otter	$8.74 X 10^{12}$	$12{,}838.7 \times 10^{12}$	371.2×10^{12}	$12{,}847.4 \times 10^{12}$

The United States Fish and Wildlife Service has been provided with copies of these TMDLs.

III. Discussion of Regulatory Conditions

EPA finds that Virginia has provided sufficient information to meet all of the 8 basic requirements for establishing a fecal coliform TMDL for the Big Otter River. EPA therefore approves these TMDLs . Our approval is outlined according to the regulatory requirements listed below.

1) The TMDL is designed to meet the applicable water quality standards.

Virginia has indicated that excessive levels of fecal coliform due to nonpoint sources have caused violations of the water quality standards and designated uses on the Big Otter River, Sheep Creek, Elk Creek, Machine Creek, and the Little Otter River. The water quality criterion for fecal coliform is a geometric mean 200 cfu (colony forming units)/100ml or an instantaneous standard of no more than 1,000 cfu/100ml. Two or more samples over a 30-day period are required for the geometric mean standard. Due to the number of streams involved and limitations in financial and personnel resources, the Commonwealth is only able to sample most streams once a month. Therefore, these streams were listed for violations of the instantaneous standard. Sampling on these streams will continue to determine if the load reductions called for in the TMDL allow the streams to attain standards. The sampling methodology will change to the geometric mean (two or more samples per month), once a ten percent (or less) violation rate has been observed.

The same sampling methodology will be employed when the new bacteriological (e-coli and enterococci) standards are adopted. However, the concentration of e-coli and enterococci will differ from the concentration of fecal coliform in the current standards. EPA's recommended steady-state geometric mean values for these water quality criteria for bacteria are 33 enterococci per 100 ml and 126 e-coli per 100 ml for fresh water[3]. A state might adopt these values as its water quality standard(s) or such other values as it can demonstrate they are protective of the use for which a particular waterbody is designated.

The HSPF model is being used to determine the fecal coliform deposition rates to the land as well as loadings to the stream from point and other direct deposit sources necessary to support the fecal coliform water quality criterion and primary contact use. The following discussion is intended to describe how controls on the loading of fecal coliform to the Big Otter River, Sheep Creek, Machine Creek, Elk Creek, and Little Otter River will ensure that the criterion is attained.

The TMDL modelers determine the fecal coliform production rates within the watershed. Information is attained from a wide array of sources on the farm practices in the area (land application rates of manure), the amount and concentration of farm animals, point sources in the watershed, animal access to the stream, wildlife in the watershed, wildlife fecal production rates, land uses, weather, stream geometry, etc. This information was put into the model. The model then combines all the data to determine the hydrology and water quality of the stream.

[3]USEPA. 2000. *Implementation Guidance for Ambient Water Quality for Bacteria – 1986*. EPA-823-D-00-001. U.S. Environmental Protection Agency, Office of Water.

The hydrology component of the model for all the Big Otter TMDLs was developed using United States Geologic Survey (USGS) gages #02061000 and #02061500 on the upper and lower Big Otter River respectively. Gage #02061000 had flow data from October of 1943 to September of 1960, while gage#02061500 had flow data from April of 1937 to September of 1999. A regression relationship was developed in order to derive flow in the upper watershed from the data in the lower watershed (gage# 02061500). The regression analysis was run for two separate periods Oct. 1, 1943 - Sep.30, 1950 and Oct. 1, 1950 - Sep.30, 1960. The regression was used to determine if there were any changes in the response of either the upper or lower Big Otter during the 1943 -1960 study period. There was a strong correlation between the two stations. The hydrology developed on the Big Otter was transferred to the other watersheds, as there were no stream gages on the other stream segments.

Weather data is one of the mechanisms that drives the hydrology, as precipitation provides flow to the stream. The weather data for this model was obtained from several weather stations and precipitation gages in the watershed. Precipitation gages at the Lynchburg Municipal Airport and Altavista provided most of the weather data.

The hydrology was calibrated to gage #02061500 using data from Jan. 01, 1990 through May 31, 1995. Data from Jan. 01, 1996 through Dec. 31, 1998 was used to validate the model. Additional validation runs were developed on the estimated flow data from USGS station 02061000 (this station only had data until 1960), this measured the transferability of the model. The observed and simulated data closely matched each other for the initial calibration period for gage #02061500. The percent error for the validation runs was well within the accepted range.

EPA believes that using HSPF to model and allocate fecal coliform will ensure that the designated uses and water quality standards will be attained and maintained for the Big Otter River, Little Otter River, Elk Creek, Machine Creek, and Sheep Creek.

2) The TMDL includes a total allowable load as well as individual waste load allocations and load allocations.

Total Allowable Loads

Virginia indicates that the total allowable loading of fecal coliform is the sum of the loads allocated to land based, precipitation driven nonpoint source areas (commercial land, cropland, forest, high density residential, pasture, rural residential), directly deposited nonpoint sources of fecal coliform (cattle in-stream, wildlife, straight pipes, and failed septic systems), and point sources. Activities such as the application of manure, fertilizer, and the deposition of wastes from grazing animals are considered fluxes to the land use categories. The actual value for the total fecal load can be found in Tables 3a-e of this document. The total allowable load is calculated on an annual basis due to the nature of HSPF model.

Waste Load Allocations

Virginia has stated that there are fourteen point sources discharging to the study area.

Seven of the fourteen point sources are actually discharging to an impaired watershed. Four of the fourteen point sources are not permitted to discharge fecal coliform and would not have this pollutant associated with their waste stream. EPA regulations require that an approvable TMDL include individual WLAs for each point source. According to 40 CFR 122.44(d)(1)(vii)(B), "Effluent limits developed to protect a narrative water quality criterion, a numeric water quality criterion, or both, are consistent with assumptions and requirements of any available WLA for the discharge prepared by the State and approved by EPA pursuant to 40 CFR 130.7." Furthermore, EPA has authority to object to the issuance of any NPDES permit that is inconsistent with the WLAs established for that point source.

Table 2 - Lists all of the Point Sources in the Big Otter Watershed.

Facility	Permit Number	Watershed
Gunnoe Sausage Company	VA0001449	Elk Creek*
Otter River Elementary School	VA0020851	Elk Creek*
Thraxton Elementary School [B]	VA0020869	Little Otter River
Liberty High School	VA0020796	Little Otter River
Dillons Trailer Park	VA0087840	Little Otter River
City of Bedford STP	VA0022390	Little Otter River
City of Bedford WTP [A]	VA0001503	Little Otter River
New London Academy	VA0020826	Buffalo Creek**
Alum Springs Shopping Center	VA0078999	Buffalo Creek**
Hill City Swim Club [A]	VA0089311	Buffalo Creek**
Blue Ridge Stone Company [A]	VA0050628	Flat Creek**
Briarwood Village STP	VA0031194	Flat Creek**
Body Camp Elementary School	VA0020818	Machine Creek
Otter River WTP	VA0078646	lower Big Otter

A -Permit does not contain a fecal coliform limit.
* -Not discharging to the impaired segment.
**-Stream segment is not impaired.
B - After the development of the TMDL it was determined that facility did not discharge to the Little Otter River

All of the point sources which are permitted to discharge fecal coliform (other than Gunnoe Sausage Company) are required to chlorinate. All of these facilities (other than Gunnoe) are permitted to discharge fecal coliform at a rate of 200 cfu/ 100 ml. Gunnoe Sausage is permitted to discharge an average fecal concentration of 200 cfu/100 ml and a maximum concentration of 400 cfu/100 ml. The concentration of fecal coliform in the effluent of facilities which are required chlorinate is most likely far lower than their permitted concentration of 200 cfu/ 100 ml. Proper chlorination often reduces the concentration of fecal coliform to less than 15 cfu/ 100 ml. Many of these dischargers were modeled as not contributing a fecal coliform load to the impaired segments due to chlorination in the existing condition runs. However, for the allocation scenarios, each facility was modeled as discharging at its permitted limit. Model runs demonstrate that even if the loading from these sources was zeroed out, wildlife contributions would still cause a violation of the standard.

Gunnoe Sausage Company and Otter River Elementary School discharge downstream of the impaired segment of Elk Creek. Based on data obtained from the permits a total loading for each of these sources was determined. Point sources represented a small portion of the total loading even if they discharge at their permitted levels (which most are not as they are required to chlorinate). There were no reductions needed from point sources.

The fecal coliform loading from Gunnoe Sausage Company and River Otter Elementary School did not effect the impaired segment of Elk Creek (since their discharge did not flow into this segment). However, the loads from both of these facilities were modeled to the lower Big Otter River. Therefore, their WLA is associated with the lower Big Otter not Elk Creek. Briarwood Village STP, New London Academy, and Alum Springs Shopping Centers all discharged their effluent to an unimpaired segment, however, their discharge was modeled as going to the lower Big Otter as well. Therefore, their WLA is associated with the lower Big Otter River. All of these dischargers were given a WLA equivalent to their permit limits. Table 2b lists the WLAs associated with each point source in cfu/year.

Table 2b - Waste Load Allocations (WLAs) for each point source.

Facility	Watershed	WLA (cfu/yr)
Thraxton Elementary School	Little Otter River	N/A
Liberty High School	Little Otter River	6.83×10^{10}
Dillons Trailer Park	Little Otter River	4.99×10^{10}
City of Bedford STP	Little Otter River	5.53×10^{12}
City of Bedford WTP	Little Otter River	N/A
Gunnoe Sausage Company	Elk Creek	1.07×10^{12}

Otter River Elementary School	Elk Creek	1.24×10^{11}
New London Academy	Buffalo Creek	1.11×10^{10}
Alum Springs Shopping Center	Buffalo Creek	1.10×10^{12}
Hill City Swim Club	Buffalo Creek	N/A
Blue Ridge Stone Company	Flat Creek	N/A
Briarwood Village STP	Flat Creek	6.64×10^{11}
Body Camp Elementary School	Machine Creek	1.24×10^{11}
Otter River WTP	Big Otter	N/A

N/A - There are no fecal coliform limits in the permit.

The waste load allocation for Little Otter River is the sum of the WLAs from Liberty High School, Dillon's Trailer Park, and City of Bedford STP. The waste load allocation for Machine Creek is equal to the waste load allocation for Body Camp Elementary School. The waste load allocation for the lower Big Otter is equal to the summation of all of the waste load allocations listed in Table 2b.

Load Allocations

According to federal regulations at 40 CFR 130.2 (g), load allocations are best estimates of the loading, which may range form reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting loading. Wherever possible natural and nonpoint source loads should be distinguished.

In order to accurately simulate landscape processes and nonpoint source loadings, VA DEQ used the HSPF model to represent the Big Otter River Watershed. The HSPF model is a comprehensive modeling system for simulation of watershed hydrology, point and nonpoint loadings, and receiving water quality for conventional pollutants and toxicant[4]. More specifically HSPF uses precipitation data for continuous and storm event simulations to determine total fecal loading to the Big Otter River Watershed from all land sources. The total land loading of fecal coliform is the result of the application of manure, direct deposition from cattle and wildlife (geese, deer, muskrat, racoon, etc.) to the land, fecal coliform production from dogs, and application of sludge.

In addition, VADEQ recognizes the significant loading of fecal coliform from cattle in-stream, straight pipes, wildlife in-stream, and failed septic systems. These sources are not dependent on a transport mechanism to reach a surface waterbody and therefore can impact

[4] Supra, footnote 2.

water quality during low and high flow events.

Tables 3a-e illustrate the load allocations for all nonpoint sources of fecal coliform.

Table 3a -Load allocation for all nonpoint sources of fecal coliform for Sheep Creek

Source	Existing Load $(\times 10^{12})$ (cfu/yr)	Allocated Load $(\times 10^{12})$ (cfu/yr)	Percent Reduction
Commercial Land	<0.01	<0.01	0
Cropland	1.07	0.43	60
Forest	35.68	35.68	0
High Density Residential	0.03	0.03	0
Pasture	4,112.79	1,645.12	60
Rural Residential	9.99	9.99	0
Cattle In-Stream	96.3	0.0	100
Wildlife In-Stream	19.6	3.9	80
Straight Pipes	8.9	0.0	100
Total	4,284.36	1,695.15	60

Table 3b - Load allocation for the land application of fecal coliform for Elk Creek

Source	Existing Load $(\times 10^{12})$ (cfu/yr)	Allocated Load $(\times 10^{12})$ (cfu/yr)	Percent Reduction
Commercial Land	0.01	0.01	0
Cropland	0.06	0.02	60
Forest	19.19	19.19	0
High Density Residential	0.39	0.39	0
Pasture	5,697.95	2,279.18	60
Rural Residential	106.71	106.71	0
Cattle In-Stream	138.8	4.2	97
Wildlife In-Stream	39.7	11.9	70

Straight Pipes	1.8	0.0	100
Total	6,004.61	2,421.6	60

Table 3c - Load allocation for the land application of fecal coliform for Machine Creek

Source	Existing Load ($\times 10^{12}$) (cfu/yr)	Allocated Load ($\times 10^{12}$) (cfu/yr)	Percent Reduction
Commercial Land	<0.01	<0.01	0
Cropland	0.13	0.05	60
Forest	1.49	1.49	0
High Density Residential	0.01	0.01	0
Pasture	996.32	398.53	60
Rural Residential	3.30	3.30	0
Cattle In-Stream	126.6	0.0	100
Wildlife In-Stream	31.9	11.2	65
Straight Pipes	0.0	0.0	0
Total	1,159.76	414.59	64

Table 3d - Load allocation for the land application of fecal coliform for Little Otter River

Source	Existing Load ($\times 10^{12}$) (cfu/yr)	Allocated Load ($\times 10^{12}$) (cfu/yr)	Percent Reduction
Commercial Land	0.01	0.01	0
Cropland	0.11	0.04	60
Forest	8.14	8.14	0
High Density Residential	78.11	78.11	0
Pasture	3,136.00	1,254.4	60
Rural Residential	24.87	24.87	0
Cattle In-Stream	130.4	0	100

Wildlife In-Stream	41.00	12.30	70
Straight Pipes	1.8	0.0	100
Total	3,420.44	1,377.87	60

Table 3e - Load allocation for the land application of fecal coliform for Big Otter River

Source	Existing Load $(\times 10^{12})$ (cfu/yr)	Allocated Load $(\times 10^{12})$ (cfu/yr)	Percent Reduction
Commercial Land	0.01	0.01	0
Cropland	0.17	0.08	50
Forest	86.26	86.26	0
High Density Residential	0.55	0.55	0
Pasture	1,998.26	999.13	50
Rural Residential	31.54	31.54	0
Cattle In-Stream	96.1	0.0	100
Wildlife In-Stream	40.9	20.5	50
Straight Pipes	1.8	0.0	100
Total	2,255.6	1,138.1	50

Please note that table 3e identifies the load allocations from sources within the impaired segment of the lower Big Otter only. In order to determine the full load allocation the total loading from table 3e must be combined with the loading from each impaired segment plus the loading from Buffalo and Flat Creek ($2{,}161.6 \times 10^{12}$ and $3{,}629.9 \times 10^{12}$ respectively) as well. The point source loading from the Buffalo Creek, Elk Creek, and Flat Creek must be subtracted from this total loading as they have been incorporated into the waste load allocation. The total loading is documented in table 1f.

3) The TMDL considers the impacts of background pollution.

A background concentration was set for all land segments by adding an additional 10% of the total wildlife load to each land segment and the stream itself.

4) The TMDL considers critical environmental conditions.

EPA regulations at 40 CFR 130.7 (c)(1) require TMDLs to take into account critical conditions for stream flow, loading, and water quality parameters. The intent of this requirement is to ensure that the water quality of the Big Otter River Watershed is protected during times when it is most vulnerable.

Critical conditions are important because they describe the factors that combine to cause a violation of water quality standards and will help in identifying the actions that may have to be undertaken to meet water quality standards[5]. Critical conditions are a combination of environmental factors (e.g., flow, temperature, etc.), which have an acceptably low frequency of occurrence but when modeled to, insure that water quality standards will be met for the remainder of conditions. In specifying critical conditions in the waterbody, an attempt is made to use a reasonable "worst-case" scenario condition. For example, stream analysis often uses a low-flow (7Q10) design condition because the ability of the waterbody to assimilate pollutants without exhibiting adverse impacts is at a minimum.

The sources of bacteria for these stream segments were mixtures of dry and wet weather driven sources. Therefore, the critical condition for the Big Otter River Watershed was represented as a typical hydrologic year. However, the most stringent reductions were needed to insure that water quality standards were met during extreme low flow conditions. During these low flow conditions, only wastes directly deposited to the stream, reach the stream. The greatest violations were recorded in the summer months.

5) The TMDLs consider seasonal environmental variations.

Seasonal variations involve changes in stream flow as a result of hydrologic and climatological patterns. In the continental United States, seasonally high flow normally occurs during the colder period of winter and in early spring from snow melt and spring rain, while seasonally low flows typically occur during the warmer summer and early fall drought periods. Consistent with our discussion regarding critical conditions, the HSPF model and TMDL analysis will effectively consider seasonal environmental variations.

6) The TMDLs include a margin of safety.

This requirement is intended to add a level of safety to the modeling process to account for any uncertainty. Margins of safety may be implicit, built into the modeling process by using conservative modeling assumptions, or explicit, taken as a percentage of the wasteload allocation, load allocation, or TMDL.

Virginia includes an explicit margin of safety by establishing the TMDL target water quality concentration for fecal coliform at 190 cfu/ 100mL, which is more stringent than Virginia's water quality standard of 200 cfu/100 mL. This would be considered an explicit 5% margin of safety.

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[5]EPA memorandum regarding EPA Actions to Support High Quality TMDLs from Robert H. Wayland III, Director, Office of Wetlands, Oceans, and Watersheds to the Regional Management Division Directors, August 9, 1999.

7) The TMDLs have been subject to public participation.

This TMDL was subject to a number of public and private meetings. Three public meetings were held to discuss the TMDL and TMDL process. The meetings were held on March 16, 2000, May 23, 2000, and August 2, 2000 and were intended to address questions and concerns regarding outreach the TMDL and TMDL process.

8) There is a reasonable assurance that the TMDL can be met.

EPA requires that there be a reasonable assurance that the TMDL can be implemented. WLAs will be implemented through the NPDES permit process. According to 40 CFR 122.44(d)(1)(vii)(B), the effluent limitations for an NPDES permit must be consistent with the assumptions and requirements of any available WLA for the discharge prepared by the state and approved by EPA. Furthermore, EPA has authority to object to issuance of an NPDES permit that is inconsistent with WLAs established for that point source.

Nonpoint source controls to achieve LAs can be implemented through a number of existing programs such as Section 319 of the Clean Water Act, commonly referred to as the Nonpoint Source Program. Additionally, Virginia's Unified Watershed Assessment, an element of the Clean Water Action Plan, could provide assistance in implementing this TMDL.

The TMDL in its current form is designed to meet the applicable water quality standards. However, due to the wildlife issue that was previously mentioned, the Commonwealth believes that it may be appropriate to modify its current standards to address the problems associated with wildlife loadings. It is believed that either because of the violation rate associated with the wildlife loadings and/or because of any modifications that may be made, that phase 1 of the implementation process will allow the Big Otter River Watershed to attain standards. The Commonwealth is investigating changing the use of these waters, adding a minimum flow component, or having a natural condition amendment added to their standards.

Fecal Coliform TMDL for Sheep Creek, Elk Creek, Machine Creek, Little Otter River, and Lower Big Otter River in Bedford and Campbell Counties, Virginia

Submitted by

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1 EXECUTIVE SUMMARY

1.1 Background

The Virginia Department of Environmental Quality (VADEQ) has identified five stream segments within the Big Otter River (BOR) basin as being impaired by fecal coliform, specifically, Sheep Creek, Elk Creek, Machine Creek, Little Otter River, and the BOR. The BOR basin is 388 square miles in area and is located in Bedford and Campbell Counties of Virginia. The BOR is a tributary of the Roanoke River (USGS Hydrologic Unit Code 03010101), which discharges into Buggs Island Lake, Lake Gaston, and continues to discharge into Albemarle Sound on North Carolina's coast. A brief description of the impaired stream segments is presented in Table 1.1. The Virginia Department of Conservation and Recreation (VADCR) has assessed BOR as having a high potential for nonpoint source pollution from agricultural lands (USEPA, 1998a). In addition, urban nonpoint sources were cited for the Little Otter River watershed. The BOR basin includes eight watersheds, five of which have impaired segments. The other three watersheds (North Otter Creek, Buffalo Creek, and Flat Creek watersheds) were considered in this study because they contribute flow and fecal coliform to the impaired segments. Forest and pasture lands comprise about 86% of the BOR basin area. The rest of the area is divided into cropland (2.03%), rural residential (6.66%), commercial/industrial (1.09%), and high density residential (4.22%), which includes the City of Bedford and parts of the City of Lynchburg.

Table 1.1 Impairment segments within the Big Otter River Basin.

Impairment	Upstream Limit	Downstream Limit	Miles Affected
Sheep Creek	Off route 614 near Reba	Confluence with Stony Creek	7.33
Elk Creek	Rt. 643 bridge east of forest	Elk Creek mouth on Big Otter River	7.48
Machine Creek	Intersection of Rts. 24 & 732	Machine Creek mouth on Little Otter River	20.00
Little Otter River	Rt. 680 Cobbs Mt.	Little Otter River mouth on Big Otter River	27.22
Big Otter River	Confluence with Buffalo Creek	Big Otter Mouth on Roanoke River [from revised 303d]	14.75

Water quality samples in the five impaired segments were taken between July 1979 and December 1998. The specific periods during which the water quality samples were taken in each sub-watershed are given in Chapters 4-8. The water samples had fecal coliform concentrations that exceeded the instantaneous 1000 cfu/100mL standard in 60%, 26%, 61%, 28% and 23% for Sheep Creek, Elk Creek, Machine Creek, Little Otter River, and Lower Big Otter River, respectively. The instantaneous standard specifies that fecal coliform concentrations in the stream shall not exceed 1000 colony forming units (CFU) per 100 mL.

Because of the water quality impairment, the BOR was assessed as not supporting the Clean Water Act's Swimming Use Support Goal for the 1998 305(b) report and was included in the 303(d) list (USEPA, 1998a, and b). In order to remedy the water quality impairment pertaining to fecal coliform, a Total Maximum Daily Load (TMDL) has been developed for each impaired segment, taking into account all sources of fecal coliform and a margin of safety (MOS). Upon implementation, the TMDL for the BOR basin shall ensure that the water quality standard relating to fecal coliform will be in compliance with the geometric mean standard. The geometric mean water quality standard specifies that the 30-day geometric mean concentration of fecal coliform shall not exceed 200 cfu/100 mL.

1.2 Sources of Fecal Coliform

Fecal coliform in the impaired segments of the BOR basin originate from agricultural, residential, and wildlife, and from inflow from North Otter Creek, Buffalo Creek, and Flat Creek watersheds. Animal waste directly deposited or spread on pastures and cropland is subject to wash-off from rainstorms, while cattle access to streams results in direct fecal coliform loading. Similarly, wildlife sources contribute to fecal loads through direct deposition in the stream as well as deposition on land surfaces that are subject to wash-off. A brief description of specific sources of fecal coliform in each sub-watershed is included in the following sections.

1.2.1 Sheep Creek

There are no permitted point sources of fecal coliform discharging to the Sheep Creek. Animal operations in the Sheep Creek watershed include beef, two dairies, and horses. Although the total number of animals is available, the specific number of beef operations and horse farms is unknown. Non-agricultural nonpoint sources of fecal coliform loadings include failing septic systems, wildlife, and pet waste subject to wash-off. Based on modeling assumptions and best professional judgement, it was projected in the Sheep Creek watershed that there were eight incidences of direct discharge of household wastewater (straight pipes) to the stream, and 194 failing septic systems.

1.2.2 Elk Creek

There are two permitted point sources of fecal coliform discharging to Elk Creek -- Otter River Elementary School (not currently discharging fecal coliform due to discharging requirements), and the Gunnoe Sausage Co. Based on a monthly grab sampling interval, the Gunnoe Sausage Co. is permitted to discharge an average fecal coliform concentration of 200 cfu/100 mL with a maximum concentration of 400 cfu/100 mL. Neither of these permitted discharges contributes to the flow reaching the stream segment listed as impaired. Animal operations in the Elk Creek watershed include beef, two dairies, and horses.   Although total number of animals is available, the specific number of beef operations and horse farms is unknown. Non-agricultural nonpoint sources of fecal coliform loadings include failing septic systems, wildlife, and pet waste subject to wash-off. Based on modeling assumptions and best professional judgement, it was projected that in the Elk Creek watershed there was one incidence of direct discharge of household wastewater (straight pipes) to the stream, and 378 failing septic systems.

1.2.3 Machine Creek

There is one permitted point sources of fecal coliform in the Machine Creek watershed (Body Camp Elementary School), but it is not currently discharging fecal coliform due to chlorination requirements. Animal operations in the Machine Creek watershed include beef and horses. Although the total number of animals is available, the specific number of beef operations and horse farms is unknown. Non-agricultural nonpoint sources of fecal coliform loadings include failing septic systems, wildlife, and pet waste subject to wash-off. Based on modeling assumptions and best professional judgement, it was projected that in the Machine Creek watershed there was no incidence of direct discharge of household wastewater (straight pipes) to the stream, but a total of 163 failing septic systems were estimated.

1.2.4 Little Otter River

There are four permitted point sources of fecal coliform in the Little Otter River watershed but none are currently discharging fecal coliform due to chlorination requirements. Animal operations in the Little Otter River watershed include beef cattle, two dairies, and horses. Although the total number of animals is available, the specific number of beef operations and horse farms is unknown. Non-agricultural nonpoint sources of fecal coliform loadings include failing septic systems, wildlife, and pet waste subject to wash-off. Based on modeling assumptions and best professional judgement, it was projected that in the Little Otter River watershed there was one incidence of direct discharge of household wastewater (straight pipes) to the stream, and 338 failing septic systems. The Little Otter River also receives outflow from Machine Creek near the outlet of the Little Otter River watershed.

1.2.5 Lower Big Otter River

There are no permitted point sources of fecal coliform in the Lower Big Otter River Hydrologic Unit (HU). Animal operations in the Lower Big Otter River HU include horses, beef cattle, and one dairy. Although the total number of animals is available, the specific number of beef operations and horse farms is unknown. Non-agricultural nonpoint sources of fecal coliform loadings include failing septic systems, wildlife, and pet waste subject to wash-off. Based on modeling assumptions and best professional judgement, it was projected that in the Lower Big Otter River HU there was one incidence of direct discharge of household wastewater (straight pipes) to the stream, and 304 failing septic systems. The Lower Big Otter River HU is located at the downstream end of the BOR basin. The segment listed as impaired in the Lower Big Otter River HU receives inflows from the entire BOR basin. These inflows from each of the other watersheds in the BOR basin were incorporated into the Lower Big Otter River HU simulations.

1.3 Modeling

The Hydrologic Simulation Program – FORTRAN (HSPF) was used to simulate the fate and transport of fecal coliform bacteria in the five impaired stream segments within the BOR basin. The BASINS (Better Assessment Science Integrating Point and Nonpoint Sources System) Version 2.0 interface was used to facilitate use of HSPF. The

HSPEXP decision support software was used to develop a calibrated HSPF data set for the BOR basin.

Modeling was conducted in phases. The headwater watersheds were modeled in the first phase, and downstream watersheds were modeled in proceeding phases. The calibration period covered a wide range of hydrologic conditions, including low- and high-flow conditions as well as seasonal variations. Data was obtained from two USGS flow-monitoring stations in the BOR basin. The primary station (Station Number 02061500) is located near the bridge on State Route 682 over the Big Otter River. The drainage area monitored at this station is 320 square miles (204,866 acres) and the available period of record is April 1937 through September 1999. The supplementary USGS station is located near Bedford, Virginia (Station Number 02061000). The drainage area monitored at station 02061000 is 116 square miles (74,264 acres) and the available period of record is October 1943 through September 1960.

The calibrated HSPF data set was validated on a separate period of record for January 1, 1996 to December 31, 1998. The calibrated HSPF model adequately simulated the hydrology of the BOR basin.

The water quality component of HSPF was calibrated for each individual watershed using fecal coliform data for the period of November 1990 to March 1998. Inputs to the model included simulated flow data and fecal coliform loadings on land and in the stream. Fecal coliform loads were estimated on a monthly basis to account for seasonal variability in production and cultural practices, considering factors such as the fraction of time cattle are in confinement, time spent in streams, and manure storage and spreading schedules. A comparison of simulated and observed fecal coliform loadings in the stream indicated that the model adequately simulated the fate of fecal coliform in each watershed.

1.4 Margin of Safety

While developing allocation scenarios to implement the TMDL, an explicit margin of safety (MOS) of 5% was used. Hence, the maximum 30-day geometric mean target for the allocation scenario was 190 cfu/100 mL, 5% below the standard (200 cfu/100 mL). It is expected that a MOS of 5% will account for any uncertainty in the model simulations, such as in the model input data.

1.5 Existing Conditions and Allocation Scenarios

Monthly fecal coliform loadings to different Land use categories were calculated for each subwatershed for input into the model. Fecal coliform content of stored waste was adjusted to account for die-off in storage prior to land application. Fecal coliform die-off on the land surface was considered, as was the reduction in fecal coliform available for surface wash-off due to incorporation following waste application on cropland. Direct seasonal fecal coliform loading in the stream by cattle was calculated for pastures adjacent to streams. Fecal coliform loadings in the stream or on land by wildlife were estimated for deer, raccoons, muskrats, and ducks. Fecal coliform loading to land from failing septic systems was estimated based on number and age of houses. Fecal coliform contribution from pet waste was also considered.

After calibrating to the existing water quality conditions, different scenarios were evaluated to identify implementable scenarios that meet the 30-day geometric mean criterion (200 cfu/100 mL) with zero violations. For the selected scenario, load allocations were calculated using the following equation:

$$TMDL = \Sigma WLA + \Sigma LA + MOS \qquad [1.1]$$

where,

WLA = wasteload allocation (point source contributions);
LA = load allocation (nonpoint source contributions); and
MOS = margin of safety, 5% of TMDL.

1.5.1 Sheep Creek Watershed

For the representative period of August 1993 through December 1998, HSPF was calibrated to the existing conditions pertaining to fecal coliform loading in Sheep Creek watershed. The primary contributors to the mean daily fecal coliform loading are direct deposition from cattle (40%), loads from pervious land segments (PLS) (38%), and direct deposition from wildlife (13%) (section 4.4). Fecal coliform loadings were significantly higher during dry periods of the summer months. Baseflow conditions allowed for little fecal coliform dilution and cattle spent more time in the water during summer, thereby increasing direct fecal coliform deposition in the stream. Results indicated frequent violations of the 200 cfu/100 mL geometric mean standard for the watershed.

Some of the scenarios evaluated for potential implementation are presented in Table 1.2. Scenarios 6 and 7 meet the TMDL allocation requirement of no violations of the 190 cfu/100mL 30-day geometric mean goal (Table 1.2). Scenario 7 was selected since it requires less reduction in NPS from agricultural land segments with only 5% more reduction in direct deposition of wildlife into streams. Loadings from direct pipes were reduced by 100% for all scenarios. Scenarios 2 and 3 (Table 1.2) indicate the significance of cattle in streams as a source of fecal coliform loading. Hence, emphasis should be placed on reducing direct deposits from cattle in the streams. The required load reductions for the TMDL allocation are listed in Tables 1.3 and 1.4 for nonpoint and direct nonpoint sources, respectively. The 30-day geometric mean fecal coliform concentrations resulting from Scenario 7, as well as the existing conditions, are presented graphically in Figure 1.1.

Table 1.2 Allocation scenarios for the Sheep Creek watershed (L23)

Scenario Number	Percent reduction in loading from existing condition				
	Direct wildlife deposits	**Direct cattle deposits**	**NPS from Ag land segments**	**Direct Pipes**	**Percentage of days with 30-day GM > 190 cfu/100mL**
1	50	90	25	100	58
2	75	90	60	100	38.7
3	75	98	60	100	5.2
4	75	100	0	100	1.3
5	75	100	50	100	1.4
6	75	100	75	100	0
7[a]	**80**	**100**	**60**	**100**	**0**

[a] Selected TMDL scenario

Table 1.3. Annual nonpoint source loads under existing conditions and corresponding reductions for TMDL allocation scenario 7 in the Sheep Creek watershed (L23)[a]

Pervious Land Segment	Existing conditions		Allocation scenario	
	Existing load ($\times 10^{12}$ cfu)	Percent of total load to stream from nonpoint sources	TMDL nonpoint source allocation load ($\times 10^{12}$ cfu)	Percent reduction from existing load
Commercial/Industrial	<0.01	< 0.1	<0.01	0
Cropland	1.07	< 0.1	0.43	60
Forest	35.68	0.9	35.68	0
High Density Residential	0.03	< 0.1	0.03	0
Pasture	4,112.79	98.9	1,645.12	60
Rural Residential	9.99	0.2	9.99	0
Total	**4,159.56**	**100.0**	**1,691.25**	**59.3**

[a] Only impaired subwatersheds

Table 1.4. Annual direct nonpoint source load reductions for TMDL allocation Scenario 7 in the Sheep Creek watershed (L23)[a]

Source	Existing Conditions		Allocation Scenario	
	Fecal coliform load ($\times 10^{12}$ cfu)	Percent of total load to stream from direct nonpoint sources	Nonpoint source allocation load ($\times 10^{12}$ cfu)	Percent reduction
Cattle in stream	96.3	77.2	0.0	100.0
Wildlife in stream	19.6	15.7	3.9	80.0
Straight Pipes	8.9	7.1	0.0	100.0
Total	**124.8**	**100.0**	**3.9**	**96.9**

[a] Only impaired subwatersheds

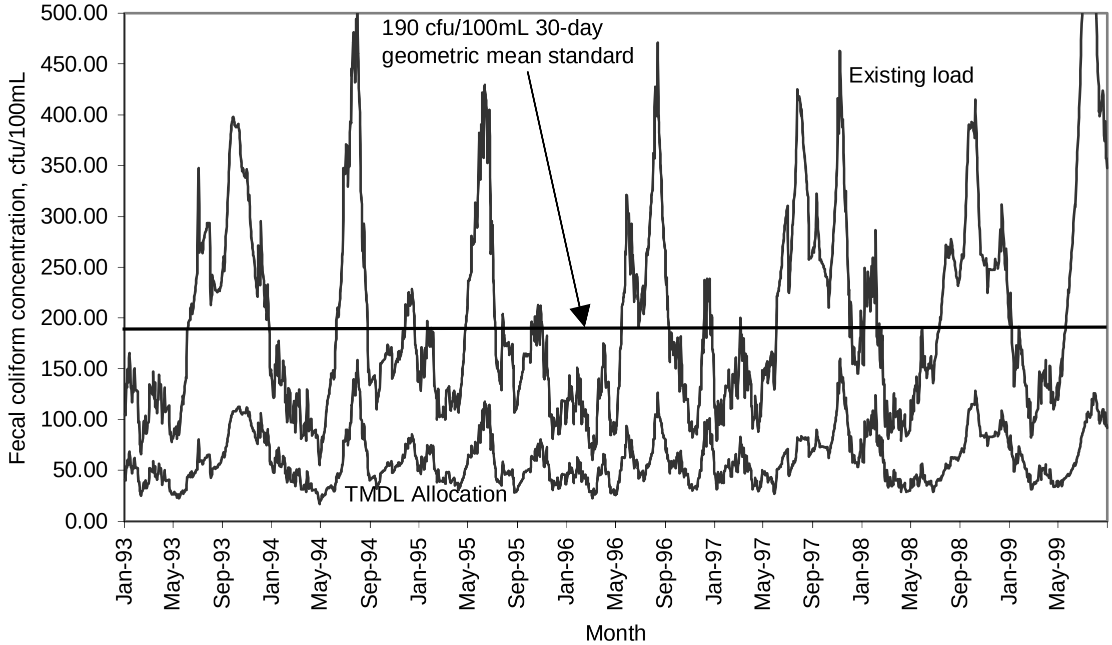

Figure 1.1. Successful TMDL allocation, 190 cfu/100 mL 30-day geometric mean goal, and existing conditions for Sheep Creek (Scenario 7, Table 1.2)

Since there are no point sources of fecal coliform in the Sheep Creek watershed, the proposed scenario requires load allocations for only the nonpoint source contributions. Based on reductions required from existing conditions and fecal coliform loadings given in Tables 1.3 and 1.4, the summary of the fecal coliform TMDL is given in Table 1.5.

Table 1.5. Annual fecal coliform loadings (cfu/year) used for developing the fecal coliform TMDL for the Sheep Creek watershed (L23)

Subwatershed	ΣWLA	ΣLA	MOS[a]	TMDL
Sheep Creek	<0.1X 10^{12}	1,695.2 X 10^{12}	89.2 X 10^{12}	1,784.4 X 10^{12}

[a] Five percent of TMDL

The TMDL allocation requires a 100% reduction of fecal coliform from direct deposits by cattle in the streams, a 100% reduction of straight pipe discharge, a 80% reduction of fecal coliform from direct deposits by wildlife, and a 60% reduction from agricultural nonpoint sources.

1.5.2 Elk Creek Watershed

For the representative period of August 1993 through December 1998, HSPF was calibrated for the existing conditions pertaining to fecal coliform loading in Elk Creek watershed. The primary contributors to the mean daily fecal coliform loading are direct deposition from cattle (44%), loads from PLS (43%), and direct deposition from wildlife (11%) (section 5.4). Fecal coliform loadings were significantly higher during base flow periods and during summer. While base flow conditions allowed for little fecal coliform dilution, cattle spent more time in the water during summer, thereby increasing direct fecal coliform deposition in the stream. Results indicated frequent violations of the 200 cfu/100 mL geometric mean standard in the watershed.

Some of the scenarios evaluated for potential implementation in the Elk Creek watershed are presented in Table 1.6. Scenarios 5 and 7 meet the TMDL allocation requirement of no violations of the 190 cfu/100mL 30-day geometric mean goal (Table 1.6). Scenario 5 was selected since it requires less reduction in direct deposition from cattle into streams. The comparison of Scenarios 1 and 2 (Table 1.5) indicates the significance of cattle in streams as a source of fecal coliform loading. Reductions in direct deposition from wildlife, loads from straight pipes, and loads from pervious land surfaces were also required to meet the TMDL goal of zero exceedances of the standard. The required load reductions for the TMDL allocation scenarios are listed in Tables 1.7 and 1.8 for nonpoint and direct nonpoint sources, respectively. The 30-day geometric mean fecal coliform concentrations resulting from Scenario 5, as well as the existing conditions, are presented graphically in Figure 1.2.

Table 1.6 Allocation scenarios for the Elk Creek watershed (L25)

Scenario	Percent Reduction in Direct Deposit from Cattle	Percent Reduction in Direct Deposit from Wildlife	Percent Reduction in Straight Pipes	Loads from Pervious Ag Land Surfaces	Percent Exceedance of 190 cfu/100mL Geometric Mean Standard
1	50	50	100	0	78.6
2	95	60	100	60	1.92
3	95	70	100	60	0.46
4	95	80	100	60	0.09
5[a]	**97**	**70**	**100**	**60**	**0.00**
6	100	50	100	30	1.60
7	100	60	100	60	0.00

[a] Selected TMDL scenario

Table 1.7. Annual nonpoint source loads under existing conditions and corresponding reductions for TMDL allocation scenario 5 in the Elk Creek watershed (L25)[a]

	Existing Conditions		Allocation Scenario	
Pervious Land Segment	**Existing load ($\times 10^{12}$ cfu)**	**Percent of total load to stream from nonpoint sources**	**TMDL nonpoint source allocation load ($\times 10^{12}$ cfu)**	**Percent reduction from existing load**
Commercial/Industrial	0.01	< 0.1	0.01	0
Cropland	0.06	< 0.1	0.02	60
Forest	19.19	0.3	19.19	0
High Density Residential	0.39	< 0.1	0.39	0
Pasture	5,697.95	97.8	2,279.18	60
Rural Residential	106.71	1.8	106.71	0
Total	**5,824.31**	**100.0**	**2,405.50**	**58.7**

[a] Only impaired subwatersheds and unimpaired subwatersheds upstream of impaired subwatersheds

Table 1.8. Annual direct nonpoint source load reductions for TMDL allocation scenario 5 in the Elk Creek watershed (L25)[a]

	Existing Conditions		Allocation Scenarios	
Source	**Existing fecal coliform load ($\times 10^{12}$ cfu/yr)**	**Percent of total load to stream from direct nonpoint sources**	**Nonpoint source allocation load ($\times 10^{12}$ cfu/yr)**	**Percent reduction**
Cattle in stream	138.8	77.0	4.2	97.0
Wildlife in stream	39.7	22.0	11.9	70.0
Straight pipes	1.8	1.0	0.0	100.0
Total	**180.3**	**100.0**	**16.1**	**91.1**

[a] Only impaired subwatersheds and unimpaired subwatersheds upstream of impaired subwatersheds

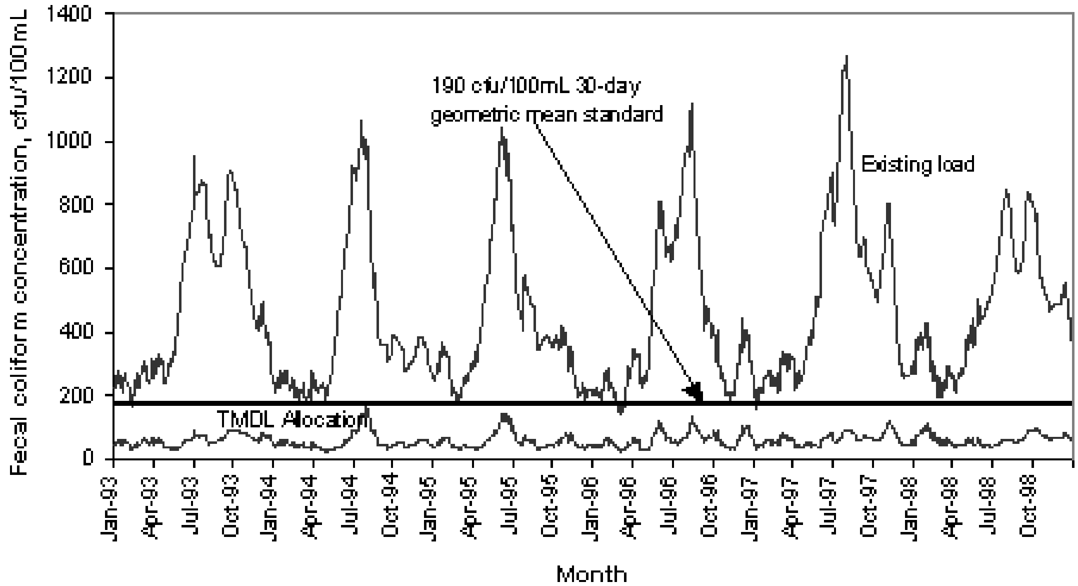

Figure 1.2. Successful TMDL allocation, 190 cfu/100 mL 30-day geometric mean goal, and existing conditions for Elk Creek (Scenario 5, Table 1.6)

Since there are no point sources of fecal coliform in the impaired segment of Elk Creek, the proposed scenario requires load allocations for only the nonpoint source contributions. Based on reductions required from existing conditions and fecal coliform loadings given in Tables 1.7 and 1.8, the summary of the fecal coliform TMDL is given in Table 1.9.

Table 1.9. Annual fecal coliform loadings (cfu/year) used for developing the fecal coliform TMDL for the Elk Creek watershed (L25)

Subwatershed	ΣWLA	ΣLA	MOS[a]	TMDL
Elk Creek	$<0.1 \times 10^{12}$	$2{,}421.6 \times 10^{12}$	127.5×10^{12}	$2{,}549.1 \times 10^{12}$

[a] Five percent of TMDL

The TMDL allocation requires a 97% reduction of fecal coliform from direct deposits by cattle in the streams, elimination of the straight pipe loads, a 60% reduction from nonpoint sources, and a 70% reduction of wildlife deposition in streams.

1.5.3 Machine Creek Watershed

For the representative period of August 1993 through December 1998, HSPF was calibrated to the existing conditions pertaining to fecal coliform loading in the Machine

Creek watershed. Direct deposition from cattle (59%) was the primary contributor to the mean daily fecal coliform loading, followed by loads from PLS (30%), and direct deposition from wildlife (10%) (section 6.4). Fecal coliform loadings were significantly higher during dry periods of the summer months. While base flow conditions allowed for little fecal coliform dilution, cattle spent more time in the water during summer, thereby increasing direct fecal coliform deposition in the stream. Results indicated frequent violations of the 200 cfu/100 mL geometric mean standard in the watershed.

Some of the allocation scenarios evaluated for the Machine Creek watershed are presented in Table 1.10. Scenario 8 meets the TMDL allocation requirement of no violations of the 190 cfu/100mL 30-day geometric mean goal (Table 1.10). Scenarios 2 through 4 (Table 1.10) indicate the significance of cattle in streams as a source of fecal coliform loading. Hence, emphasis should be placed on reducing direct deposits from cattle in the streams. The required load reductions for the TMDL allocation are listed in Tables 1.11 and 1.12 for nonpoint and direct nonpoint sources, respectively. The 30-day geometric mean fecal coliform concentrations resulting from Scenario 8, as well as the existing conditions, are presented graphically in Figure 1.3.

Table 1.10 Allocation scenarios for the Machine Creek watershed (L26a)

Scenario Number	Percent reduction in loading from existing condition				
	Direct wildlife deposits	Direct cattle deposits	NPS from Ag land segments	Direct pipes	Percentage of days with 30-day GM > 190 cfu/100mL
1	0	0	0	0	99.7
2	60	90	0	0	24.2
3	60	95	0	0	10.2
4	60	99	0	0	2.5
5	60	100	0	0	1.6
6	60	100	50	0	0.2
7	60	100	60	0	0.1
8[a]	**65**	**100**	**60**	**0**	**0.0**
9	70	100	50	0	0.0

[a] Selected TMDL scenario

Table 1.11. Annual nonpoint source loads under existing conditions and corresponding reductions for TMDL allocation scenario 8 in the Machine Creek watershed (L26a)

Pervious Land Segment	Existing conditions		Allocation scenario	
	Existing load ($\times 10^{12}$ cfu)	Percent of total load to stream from nonpoint sources	TMDL nonpoint source allocation load ($\times 10^{12}$ cfu)	Percent reduction from existing load
Commercial/ Industrial	<0.01	< 0.1	<0.01	0
Cropland	0.13	< 0.1	0.05	60
Forest	1.49	0.2	1.49	0
High Density Residential	0.01	< 0.1	0.01	0
Pasture	996.32	99.5	398.53	60
Rural Residential	3.30	0.3	3.30	0
Total	**1,001.24**	**100.0**	**403.38**	**59.7**

Table 1.12. Annual direct nonpoint source load reductions for TMDL allocation Scenario 8 in the Machine Creek watershed (L26a)

Source	Existing Conditions		Allocation Scenarios	
	Existing fecal coliform load ($\times 10^{12}$ cfu)	Percent of total load to stream from direct nonpoint sources	nonpoint source allocation load ($\times 10^{12}$ cfu)	Percent reduction
Cattle in stream	126.6	79.86	0.0	100.0
Wildlife in stream	31.9	20.14	11.2	65.0
Straight pipes	0.0	0.0	0.0	0.0
Total	**158.6**	**100**	**11.2**	**92.9**

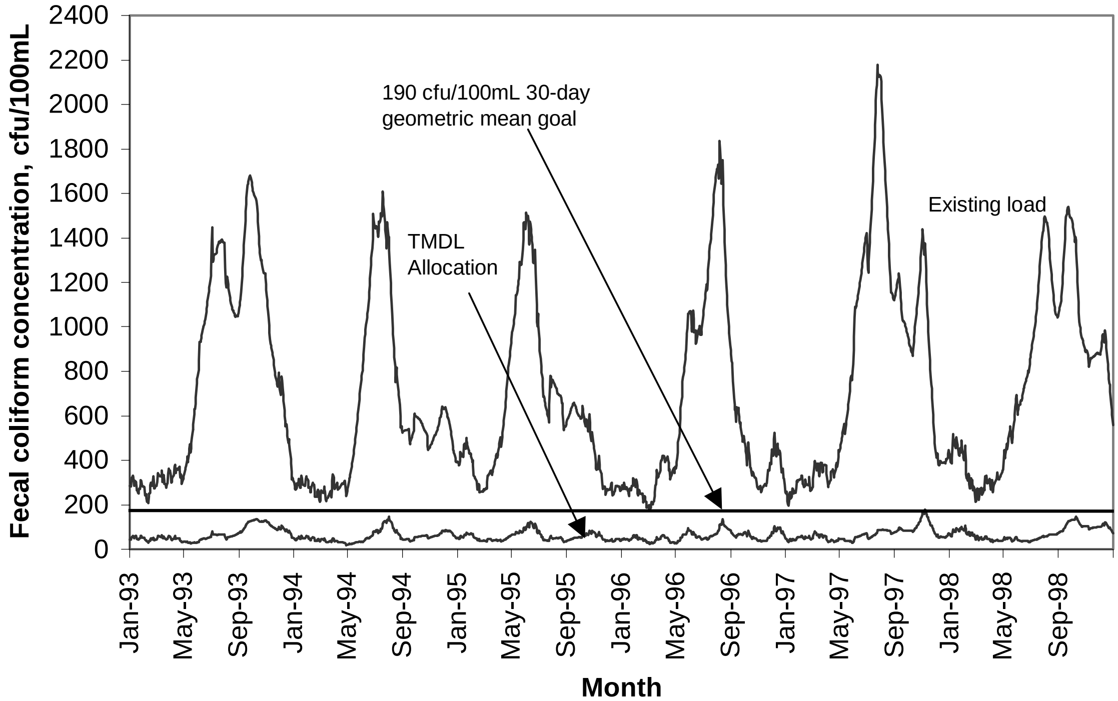

Figure 1.3 Successful TMDL allocation, 190 cfu/100 mL, 30-day geometric mean goal, and existing conditions for Machine Creek (Scenario 8, Table 1.10)

There is one point source of fecal coliform in the Machine Creek watershed. Based on reductions required from existing conditions and fecal coliform loadings given in Tables 1.11 and 1.12, the summary of the fecal coliform TMDL is given in Table 1.13. The TMDL allocation requires complete elimination of fecal coliform direct deposits by cattle in the streams, 65% reduction in direct deposit from wildlife, and 60% reduction in loads from agricultural land surfaces.

Table 1.13. Annual fecal coliform loadings (cfu/year) used for developing the fecal coliform TMDL for the Machine Creek watershed (L26a)

Subwatershed	ΣWLA	ΣLA	MOS[a]	TMDL
Machine Creek	<0.1 X 10^{12}	414.6 X 10^{12}	21.8 X 10^{12}	436.4 X 10^{12}

[a] Five percent of TMDL

1.5.4 Little Otter River Watershed

For the representative period of August 1993 through December 1998, HSPF was calibrated to the existing conditions pertaining to fecal coliform loading in the Little Otter River watershed. The primary contributors to the mean daily fecal coliform loading are loads from PLS (36%), direct deposition from cattle (12%), and direct deposition from wildlife 4% (section 7.4). Fecal coliform loadings were significantly higher during dry periods of the summer months. While base flow conditions allowed for little fecal coliform dilution, cattle spent more time in the water during summer, thereby increasing direct fecal coliform deposition in the stream. Results indicated frequent violations of the 200 cfu/100 mL geometric mean standard for the watershed.

Some of the scenarios evaluated for potential implementation are presented in Table 1.14. Scenario 11 meets the TMDL allocation requirement of no violations of the 190 cfu/100mL 30-day geometric mean goal (Table 1.13). Scenario 11 requires elimination of loads from direct pipes and combined sewer overflows (CSO) from the Bedford Sewage Treatment Plant (STP), elimination of direct fecal coliform loading to the stream from cattle, 70% reduction of direct fecal coliform loading from wildlife, and 60% reduction in loads from all pervious land uses, except from forested lands. The required load reductions for the TMDL allocation are listed in Tables 1.15 and 1.16 for nonpoint and direct nonpoint sources, respectively. The 30-day geometric mean fecal coliform concentrations resulting from Scenario 11, as well as the existing conditions, are presented graphically in Figure 1.4.

Table 1.14 Allocation scenarios for the Little Otter River watershed (L26b)

Scenario Number	Percent reduction in loading from existing condition					
	Direct wildlife deposits	Direct cattle deposits	NPS from land segments	Direct pipes	Bedford CSO	Percentage of days with 30-day GM > 190 cfu/100mL
1	0	0	0	100	100	100.0
2	0	90	0	100	100	62.0
3	0	99	0	100	100	41.2
4	0	100	0	100	100	38.3
5	50	100	0	100	100	7.9
6	60	100	0	100	100	5.3
7	60	100	25[a]	100	100	2.8
8	60	100	50[a]	100	100	0.6
9	60	100	50[b]	100	100	0.2
10	70	100	50[b]	100	100	0.1
11[c]	**70**	**100**	**60[b]**	**100**	**100**	**0.0**

[a] NPS reductions from pasture and cropland only

[b] NPS reduction from all land uses except forest

[c] Recommended allocation scenario

Table 1.15. Annual nonpoint source loads under existing conditions and corresponding reductions for TMDL allocation scenario 11 in the Little Otter River watershed (L26b)

Pervious Land Segment	Existing conditions		Allocation scenario	
	Existing load ($\times 10^{12}$ cfu)	Percent of total load to stream from nonpoint sources	TMDL nonpoint source allocation load ($\times 10^{12}$ cfu)	Percent reduction from existing load
Commercial/ Industrial	0.01	< 0.1	0.01	0
Cropland	0.11	< 0.1	0.04	60
Forest	8.14	0.2	8.14	0
High Density Residential	78.11	2.4	78.11	0
Pasture	3,136.00	96.6	1,254.40	60
Rural Residential	24.87	0.8	24.87	0
Total	**3,247.24**	**100.0**	**1,365.57**	**58.0**

Table 1.16. Annual direct nonpoint source load reductions for TMDL allocation Scenario 11 in the Little Otter River watershed (L26b)

Source	Existing conditions		Allocation Scenarios	
	Fecal coliform load (× 10^{12} cfu)	Percent of total load to stream from direct nonpoint sources	nonpoint source allocation load (× 10^{12} cfu)	Percent reduction
Cattle in stream	130.4	75.29	0.00	100.0
Wildlife in stream	41.0	23.68	12.30	70.0
Straight pipes	1.8	1.03	0.00	100.0
Total	**173.2**	**100.0**	**12.30**	**92.9**

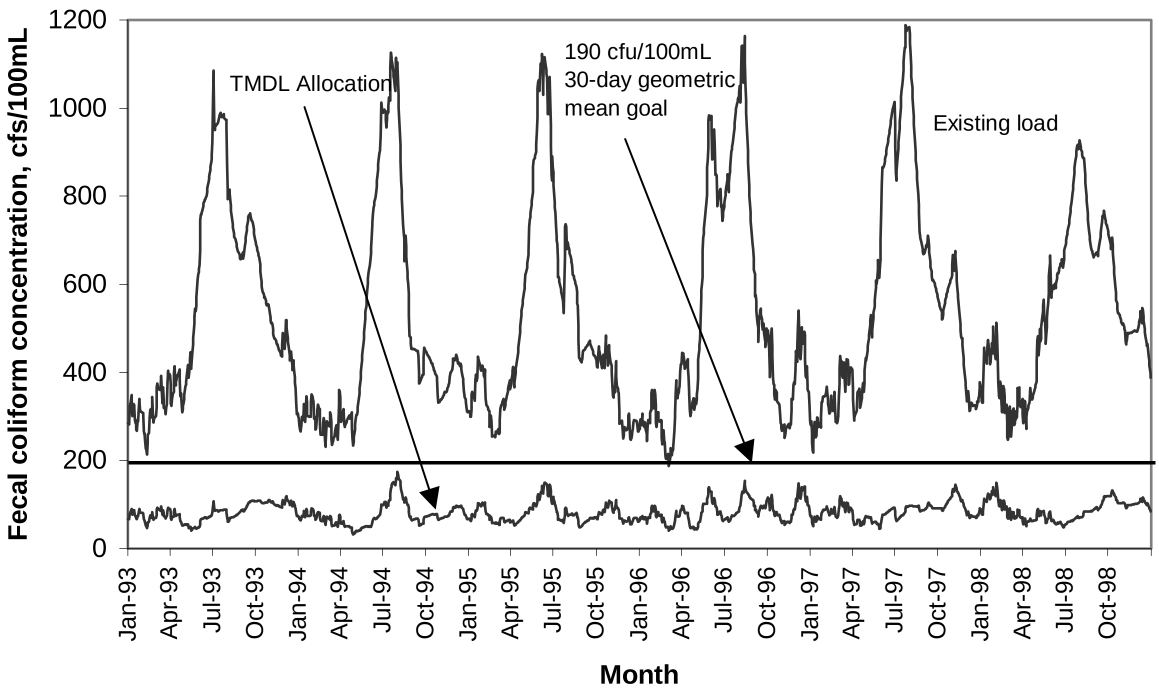

Figure 1.4. Successful TMDL allocation, 190 cfu/100 mL 30-day geometric mean goal, and existing conditions for Little Otter River (Scenario 11, Table 1.14)

There are five point sources of fecal coliform in the Little Otter River watershed. Based on reductions required from existing conditions and fecal coliform loadings given in Tables 1.15 and 1.16, the summary of the fecal coliform TMDL is given in Table 1.17.

Table 1.17. Annual fecal coliform loadings (cfu/year) used for developing the fecal coliform TMDL for the Little Otter River watershed (L26b)

Subwatershed	ΣWLA	ΣLA[a]	MOS[b]	TMDL
Little Otter River	6.8×10^{12}	$1{,}377.7 \times 10^{12}$	72.9×10^{12}	$1{,}457.4 \times 10^{12}$

[a] with LA from Machine Creek inflow of 849.4×10^{12} cfu/year

[b] Five percent of TMDL

The TMDL allocation requires the elimination of fecal coliform from direct deposits by cattle in the streams, direct pipes, and City of Bedford CSO. In addition, it requires a 70% reduction of direct deposits by wildlife in the streams, and a 60% reduction in fecal coliform loads from all pervious Land uses, except from forested lands.

1.5.5 Lower Big Otter River Watershed

For the representative period of August 1993 through December 1999, HSPF was calibrated to the existing conditions pertaining to fecal coliform loading in the Lower Big Otter River watershed. Fecal coliform loadings were significantly higher during base flow periods and during summer. While base flow conditions allowed for little fecal coliform dilution, cattle spent more time in the water during summer, thereby increasing direct fecal coliform deposition in the stream. Results indicated frequent violations of the 200 cfu/100 mL geometric mean standard in the watershed.

Some of the scenarios evaluated for potential implementation are presented in Table 1.18. Scenario 5 meets the TMDL allocation requirement of no violations of the 190 cfu/100mL 30-day geometric mean goal (Table 1.18). Scenario 5 requires a 100% reduction in direct fecal coliform loading to the stream from cattle and a 50% reduction in nonpoint sources of fecal coliform. In addition to the reductions made in the Lower Big Otter River watershed, reductions in fecal coliform loadings must be made in the watersheds upstream from the Lower Big Otter River watershed. First, TMDL implementation plans will need to be implemented in Sheep Creek, Elk Creek, Machine Creek, and the Little Otter River. Also reductions in fecal coliform loadings need to be made in North Otter Creek and Buffalo Creek. Scenarios 1 through 4 (Table 1.18) indicate the significance of upstream watersheds as a source of fecal coliform loading. The required load reductions for the TMDL allocation are listed in Tables 1.19 and 1.20 for nonpoint and direct nonpoint sources, respectively. The 30-day geometric mean fecal coliform concentrations resulting from Scenario 5, as well as the existing conditions, are presented graphically in Figure 1.5.

Table 1.18 Allocation scenarios for the Lower Big Otter River watershed (L28)

Scenario Number	Percent reduction in loading from existing condition				
	Direct cattle deposits	Direct wildlife deposits	Straight pipes	Loads from pervious land surface	Percentage of days with 30-day GM > 200 cfu/100mL
1	80	0	100	0	16.5
2	100	0	100	0	14.0
3	100	50	100	0	11.6
4[a]	100	50	100	50	0.6
5[b,c]	**100**	**50**	**100**	**50**	**0.0**
6[b]	100	30	100	40	0.9
7[b]	100	50	100	30	0.7

[a] 25% reduction in upstream load from Buffalo Creek

[b] 30% reduction in upstream load from Buffalo Creek

[c] Selected TMDL scenario

Table 1.19. Annual nonpoint source loads under existing conditions and corresponding reductions for TMDL allocation scenario 5 in the Lower Big Otter River watershed (L28)

Pervious Land Segment	Existing conditions		Allocation scenario	
	Existing load ($\times 10^{12}$ cfu)	Percent of total load to stream from nonpoint sources	TMDL nonpoint source allocation load ($\times 10^{12}$ cfu)	Percent reduction from existing load
Commercial/ Industrial	0.01	< 0.1	0.01	0
Cropland	0.17	< 0.1	0.08	50
Forest	86.26	4.1	86.26	0
High Density Residential	0.55	< 0.1	0.55	0
Pasture	1,998.26	94.4	999.13	50
Rural Residential	31.54	1.5	31.54	0
Total	**2,116.78**	**100.0**	**1,117.57**	**47.2**

Table 1.20. **Annual direct nonpoint source load reductions for TMDL allocation Scenario 5 in the Lower Big Otter River watershed (L28)**

Source	Existing conditions load (× 10^{12} cfu)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (× 10^{12} cfu)	Percent reduction
Cattle in stream	96.1	69.2	0.0	100.0
Wildlife in stream	40.9	29.5	20.5	50.0
Straight pipes	1.8	1.3	0.00	100.0
Total	**138.8**	**100.0**	**20.5**	**85.2**

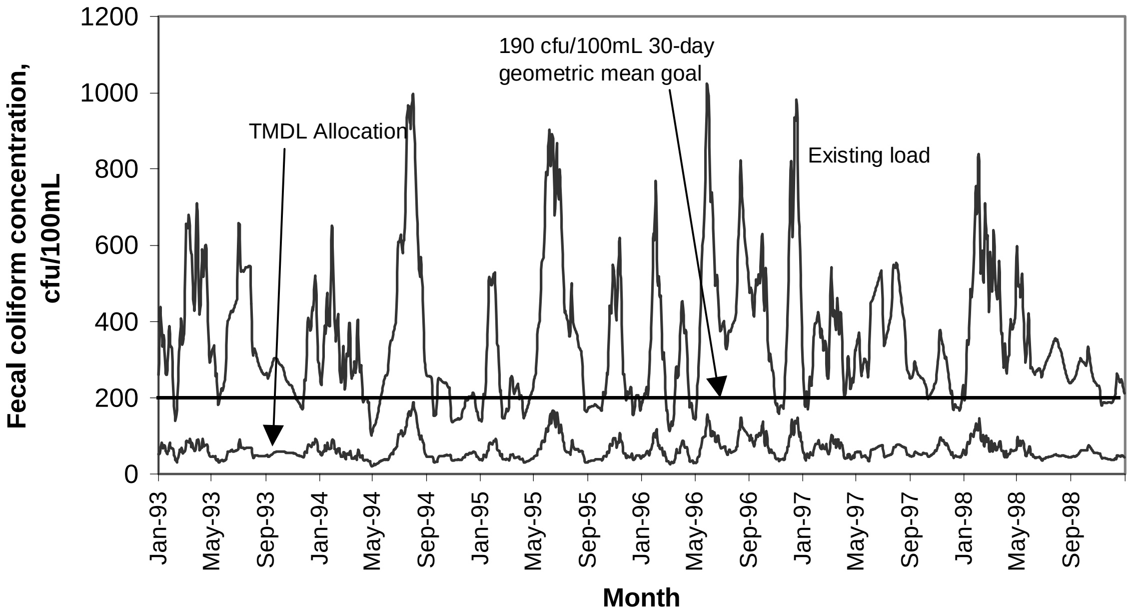

Figure 1.5. Successful TMDL allocation, 190 cfu/100 mL 30-day geometric mean goal, and existing conditions for Lower Big Otter River (Scenario 5, Table 1.18)

The segment listed as being impaired in the Lower Big Otter River watershed receives fecal coliform loads from the rest of the BOR basin. The TMDL Plan for the Lower Big Otter River watershed requires that TMDL implementation plans are implemented in the Sheep Creek, Elk Creek, Machine Creek and Little Otter River watersheds along with reductions in the loads in North Otter Creek and Buffalo Creek watersheds. Based on reductions required from existing conditions and fecal coliform loadings given in Tables 1.19 and 1.20, the summary of the fecal coliform TMDL is given in Table 1.21.

Table 1.21. Annual fecal coliform loadings (cfu/year) used for developing the fecal coliform TMDL for the Lower Big Otter River basin

Subwatershed	ΣWLA	ΣLA[a]	MOS[b]	TMDL
Big Otter River	$<0.1X10^{12}$	$1,138.1 X10^{12}$	$59.9 X10^{12}$	$1,198.0 X10^{12}$

[a] includes upstream inflows from Buffalo Creek (2161.6 $X10^{12}$ cfu/year) and Flat Creek (3629.9 $X10^{12}$ cfu/year)

[b] Five percent of TMDL

1.6 Phase 1 Implementation

A transitional scenario was evaluated that achieves smaller reductions in fecal coliform concentrations in the stream but requires less drastic changes in management practices. The implementation of such a transitional scenario, or Phase 1 implementation, will allow for an evaluation of the modeling assumptions and the effectiveness of management practices. The additional monitoring data, needed to evaluate the TMDL implementation, could be used to enhance model results if necessary. The goal of Phase 1 implementation is to achieve 10% or fewer violations of the instantaneous fecal coliform standard (1,000 cfu/100 mL) based on a monthly sampling frequency.

1.6.1 Sheep Creek Watershed

Phase 1 implementation requires a 95% reduction in direct fecal coliform loading by cattle into the stream; no reduction in direct fecal coliform loading by wildlife into the stream; elimination of all straight pipes; and a 30% reduction in loads from pervious land surfaces. This implementation scenario would result in 9% exceedances of the 1000 cfu/100 mL fecal coliform standard, according to the model.

1.6.2 Elk Creek Watershed

Phase 1 implementation requires a 63% reduction in direct fecal coliform loading by cattle into the stream, no reduction in direct fecal coliform loading by wildlife into the stream, and a 100% reduction in straight pipe loading to the stream. This implementation scenario would result in 9.7% exceedances of the 1000 cfu/100 mL fecal coliform standard.

1.6.3 Machine Creek Watershed

Phase 1 implementation requires a 80% reduction in direct fecal coliform loading by cattle into the stream. This implementation scenario would result in a 10% exceedances of the 1000 cfu/100 mL fecal coliform standard, according to the model.

1.6.4 Little Otter River Watershed

Phase 1 implementation requires a 85% reduction in direct fecal coliform loading by cattle into the stream, elimination of straight pipe fecal coliform discharge, and a 30% reduction in loads from pervious land surfaces. This implementation scenario would result in 9.9% exceedances of the 1000 cfu/100 mL fecal coliform standard, according to the model.

1.6.5 Lower Big Otter River Watershed

Phase 1 implementation requires that the Phase I implementations plans for Sheep Creek, Elk Creek, Machine Creek, and the Little Otter River be implemented. After these plans are implemented in the upstream watersheds and all straight pipes are eliminated within the Lower Big Otter River watershed, no additional reductions are required in the Lower Big Otter River watershed for the Phase I implementation.

1.7 Reasonable Assurance of Implementation

The phased TMDL implementation plan allows for the interim evaluation of the effectiveness of the proposed TMDL implementation while progressing toward compliance with Virginia's water quality standards. Phase 1 implementation allows for the evaluation of the effectiveness of management practices through frequent stream monitoring. Data collection during this phase allows for the quantification of uncertainties that affect TMDL development. By accounting for such uncertainties, the TMDL can be improved for the final implementation phase that requires full compliance with the 200 cfu/100 mL geometric mean water quality standard.

1.8 Public Participation

Public participation was elicited at every stage of the TMDL development in order to receive inputs from stakeholders and to apprise the stakeholders of the progress made. Three public meetings were organized for this purpose. The first public meeting was organized on March 16, 2000 to inform the stakeholders of the TMDL development process and to obtain feedback on animal numbers in the watershed. To better understand the nature and extent of agricultural activities in the watershed, a farm survey was mailed to landowners, and a meeting with several agricultural producers was held on April 25, 2000. Results of the hydrologic calibration and estimates of animal population and fecal production were discussed in the second public meeting on May 23, 2000. The draft TMDL report was presented at the third public meeting held on August 2, 2000.

2 INTRODUCTION

2.1 Background

Section 303(d) of the Federal Clean Water Act and the U.S. Environmental Protection Agency's (USEPA) Water Quality Planning and Management Regulations (40 CFR Part 130) (USEPA, 1998a) require states to identify waterbodies that violate state water quality standards and to develop TMDLs for such waterbodies. A TMDL reflects the total pollutant loading a water body can receive and still meet water quality standards. A TMDL establishes the maximum allowable pollutant loading from both point and nonpoint sources plus a margin of safety for a waterbody, allocates the load among the pollutant contributors, and provides a framework for taking actions to restore water quality.

Fecal pollution from both point and nonpoint sources can lead to fecal coliform bacteria contamination of waterbodies. Fecal coliform bacteria are found in the intestinal tract of warm-blooded animals; consequently, fecal waste of warm-blooded animals contains fecal coliform. Even though most fecal coliform bacteria are not pathogenic, their presence in water indicates contamination by fecal material. Since fecal material can contain other pathogenic organisms, waterbodies with high fecal coliform counts are likely to contain pathogenic bacteria, protozoa, and viruses. For contact recreational uses, e.g., boating and swimming, health risks increase with elevated fecal coliform counts in the waterbody. If the fecal coliform concentration in a waterbody exceeds state water quality standards, the waterbody is listed for violation of the state fecal coliform standard for contact recreational uses.

The VADEQ has identified five stream segments within the BOR basin as being impaired by fecal coliform, specifically, Sheep Creek, Elk Creek, Machine Creek, Little Otter River, and the Lower Big Otter River. The BOR basin is 388 square miles in area and is located in Bedford and Campbell Counties, Virginia (Figure 2.1). The BOR is a tributary of the Roanoke River (USGS Hydrologic Unit Code 03010101), which discharges into Buggs Island Lake, Lake Gaston and continues to eventually discharge into Albemarle Sound on North Carolina's coast.

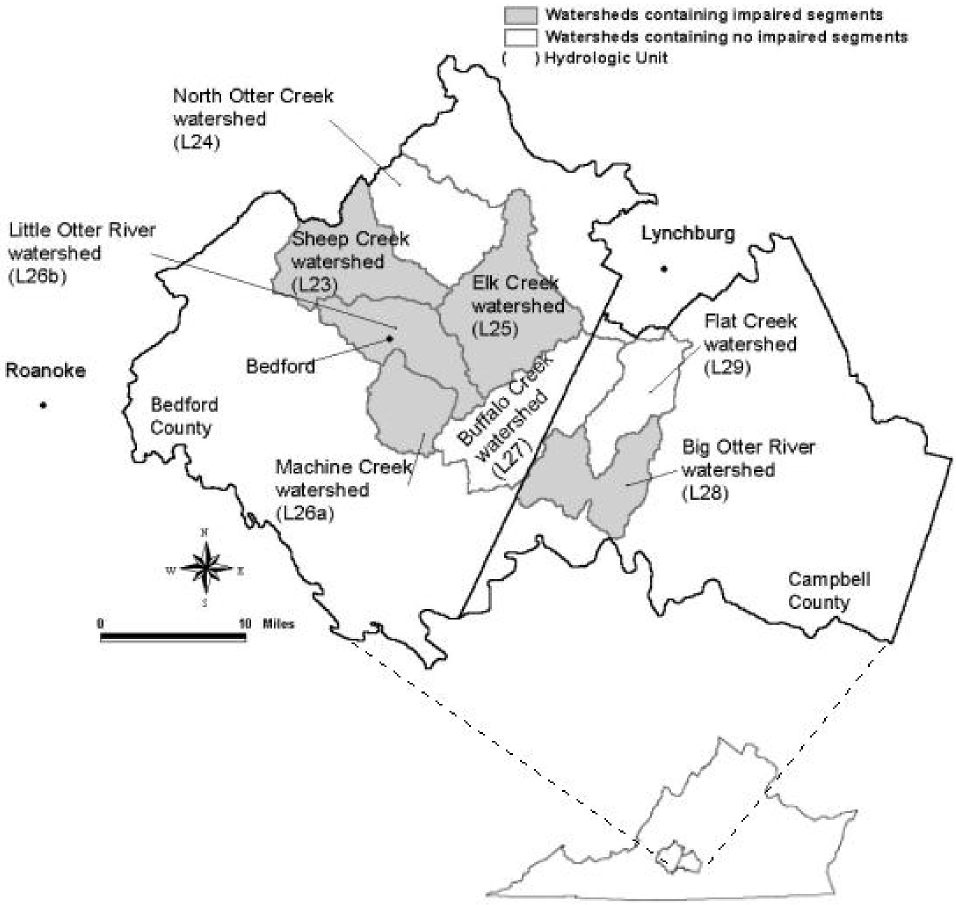

Figure 2.1. Location of the Big Otter River basin

The BOR basin includes eight watersheds, five of which include impaired segments (Figure 2.1). The other three watersheds (North Otter Creek, Buffalo Creek, and Flat Creek watersheds) were considered in this study because they contribute flow and fecal coliform to the impaired segments. Forest and pasture lands comprise about 86% of BOR basin's area. The rest of the area is divided into cropland (2%); rural residential (7%); commercial/industrial (1%), and high density residential (4%), which includes the City of Bedford and parts of the City of Lynchburg.

2.2 Applicable Water Quality Standards and Critical Conditions

For a non-shellfish supporting waterbody to be in compliance with Virginia fecal coliform standards for contact recreational use, VADEQ specifies the following criteria (VADEQ, 2000):

- Instantaneous standard: Fecal coliform count shall not exceed 1,000 colony forming units (cfu) per 100 mL at any time.

- Geometric mean standard: The geometric mean count of fecal coliform of two or more water quality samples taken within a 30-day period shall not exceed 200 cfu/100 mL.

If the waterbody exceeds either standard more than 10% of the time, the waterbody is classified as impaired and a TMDL must be developed and implemented to bring the waterbody into compliance with the water quality standard. Based on the sampling frequency, only one standard is applied to a particular datum or dataset (VADEQ, 2000). If the sampling frequency is one sample or less per 30 days, the instantaneous standard is applied; for a higher sampling frequency, the geometric mean standard is applied. For Sheep Creek, Machine Creek, Elk Creek, Little Otter River, and the Lower Big Otter River, the TMDL is required to meet the geometric mean standard, analogous to daily sample collection. The TMDL development process also must account for seasonal and annual variations in precipitation, flow, Land use, and pollutant contributions. Such an approach ensures that TMDLs, when implemented, will not result in violations under a wide variety of scenarios that affect fecal coliform loading.

2.3 The Water Quality Problem

The VADEQ has assessed the water quality conditions in the BOR basin. Fecal coliform concentrations exceeded the instantaneous standard mentioned in the previous section in five stream segments in the BOR basin. Agricultural nonpoint sources were cited as the sources of high coliform concentrations in all five watersheds based on VADEQ's best professional judgment. In addition, urban nonpoint sources were cited for the Little Otter River (USEPA, 1998a, 1998b) because some tributaries of the Little Otter River pass through the City of Bedford, Virginia.

2.4 Objective

The objective of the project was to develop a TMDL for each of the five impaired watersheds in the BOR basin that accounts for both point and nonpoint source pollutant loadings and incorporates a margin of safety to meet a zero percent violation of the state geometric mean standard for fecal coliform for non-shellfish waters.

The following tasks were performed to achieve the project objective.

1 Identified potential fecal coliform sources, including background sources, and estimated the magnitude of each source in cooperation with stakeholders;

2 Quantified fecal coliform production from each source;

3 Simulated attenuation of fecal coliform during transport from deposited locations to water bodies;

4 Accounted for variations in precipitation, hydrology, and Land use in simulating fecal coliform deposition in streams;

5 Estimated fecal coliform concentrations in waterbodies under present conditions;

6 Explored multiple scenarios to reduce fecal coliform concentrations to meet the geometric mean water quality standard;

7 Selected a TMDL that can be realistically implemented and is socially acceptable; and

8 Incorporated a margin of safety into the TMDL.

2.5 Watershed Characterization

2.5.1 Water Resources

The BOR basin has 267 miles of streams (Table 2.1) and is contained within VADCR hydrologic units (HU) L23, L24, L25, L26, L27, L28, and L29 (Figure 2.2). Sheep Creek, which is 8.80 miles in length, confluences with Stony Creek forming the BOR inside the Sheep Creek watershed (L23). The BOR then confluences with North Otter Creek (8.79 miles) at the boundaries of Sheep Creek (L23), North Otter Creek (L24), and Elk Creek (L25) watersheds and confluences with Elk Creek (24.29 miles) inside the Elk Creek watershed (L25). The BOR then confluences with its biggest tributary, the Little Otter River (26.71 miles), which in turn has Machine Creek (11.64 miles) as one of its tributaries. Both the Little Otter River and Machine Creek are within VADCR HU L26. For TMDL development, hydrologic unit L26 was subdivided into the Machine Creek watershed designated L26a and the Little Otter River watershed designated L26b.

Downstream of the confluence of BOR and the Little Otter River is the Buffalo Creek watershed (L27). Buffalo Creek (15.30 miles) confluences with BOR and finally, BOR enters the Lower Big Otter River watershed (L28) and Flat Creek (L29) confluences with the BOR (15.77 miles) downstream. The BOR ends as one of the tributaries of the Roanoke River near the Town of Altavista, Virginia.

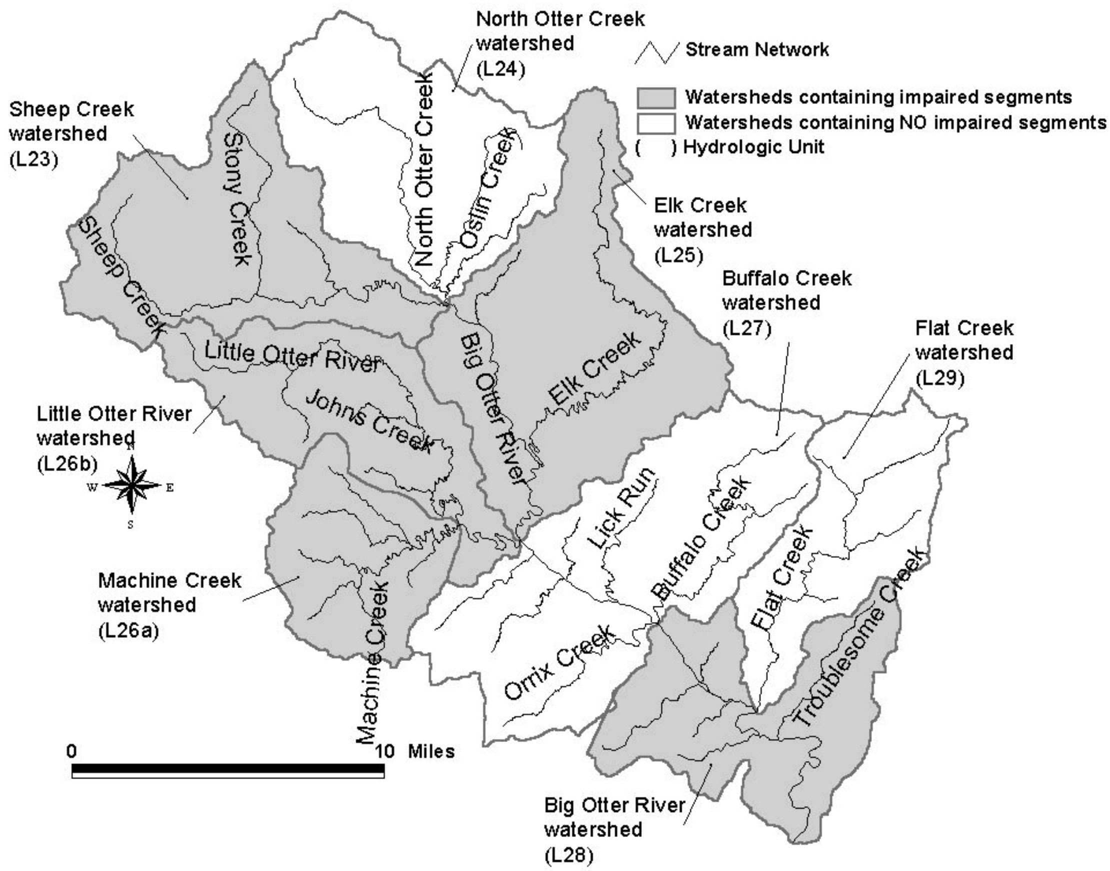

Figure 2.2. Big Otter River basin subwatersheds and stream network

Table 2.1. Total stream length in each watershed (including main streams and tributaries as used in the modeling process) of the Big Otter River (BOR) basin

Watershed	Total stream length (miles)
Sheep Creek (L23)	30.33
North Otter Creek (L24)	27.46
Elk Creek (L25)	39.60
Machine Creek (L26a)	28.04
Little Otter River (L26b)	36.09
Buffalo Creek (L27)	50.97
Big Otter River (L28)	32.39
Flat Creek (L29)	21.80
Total	**266.68**

2.5.2 Geology and Soils

Most of the BOR basin is within the Piedmont physiographic province of Virginia (VWCB, 1985). Aquifers in this area are composed of an extensive complex of igneous and metamorphic rocks of Precambrian age underlying weathered soils of varying thickness. The groundwater quality is good except for some areas with high iron concentration and acidity. The potential for pollutant movement to groundwater is moderate-to-low in these areas (VWCB, 1985). The rest of the basin, including the northwestern portion of Little Otter River watershed (L26b), the northern portion of Elk Creek watershed (L25), and large portions of Sheep Creek watershed (L23) and North Otter Creek watershed (L24), is located in the Blue Ridge physiographic province of Virginia. The Blue Ridge province provides a meager source of water due to high elevation. This province has shallower soils than the Piedmont province, and produces rapid runoff over impermeable rocks (VWCB, 1985). Groundwater quality is usually good with low potential for groundwater pollution movement (VWCB, 1985). Depth to the seasonal high water table is generally more than 6 ft in the basin (SCS, 1989). Throughout the BOR, the soils and geology do not promote movement of pollutants, such as fecal coliform, through the upper soil horizons to groundwater. Soils are relatively deep with the adequate fines to prevent percolation of bacteria. Seasonally high water tables are also generally deeper than 6 feet. Aquifers in the area are of igneous origin and are not nearly as fractured and porous as sedimentary and limestone aquifers, which are more prone to transport of bacteria.

The main soil associations delineated in the Bedford County portion of the BOR basin in order of extent, are Cecil-Madison, Hayesville-Edneytown-Braddock, Edneytown-Ashe, Nason-Tatum-Manteo, and Iredell-Poindexter-Mecklenburg. The Cecil-Madison soil association exists in the middle portion of the basin covering Machine Creek (L26a), the majority of the Little Otter River (L26b), and significant parts of Elk Creek (L25) and Buffalo Creek (L27) watersheds (SCS, 1989). Cecil-Madison soils are very deep, well drained, gently sloping to steep soils that have a clayey sub-soil. They formed in weathered mica schist and mica gneiss, or in both and weathered granite gneiss. This map unit consists of long, broad to narrow ridges dissected by short drainageways. Slopes dominantly range from about 2 to 45 percent (SCS, 1989).

Soils in the western or Blue Ridge portion of the basin are Hayesville-Edneytown-Braddock and Edneytown-Ashe associations. Hayesville-Edneytown-Braddock soils are very deep, well drained, gently sloping to very steep soils that have clayey or loamy subsoil. They formed in weathered granite or granite gneiss or in colluvial sediments. This map unit consists of long, broad to narrow ridges dissected by short drainageways and a few scattered prominent hills. Slopes range from about 2 to 60 percent. Edneytown-Ashe soils are very deep and moderately deep, well drained and somewhat excessively drained, strongly sloping to very steep soils that have clayey or loamy subsoil. They formed in weathered granite and granite gneiss. This map unit is located in the western part of the county and consists of the Blue Ridge Mountains and scattered mountain ridges and peaks of lower elevations dissected by drainageways. The mountain ridgetops are generally narrow and strongly sloping or moderately steep. The mountainsides are mostly moderately steep to very steep. Slopes range from about 7 to 60 percent (SCS, 1989). Throughout the BOR, the soils and geology do not promote the movement of pollutants such as fecal coliform through the upper soil horizons to ground water. Soils are relatively deep with adequate fines to prevent percolation of bacteria. Seasonally high water tables are also generally deeper than six feet. Aquifers in the area are of igneous origin and are not nearly as fractured and porous as sedimentary and limestone aquifers, which are more prone to transport of bacteria.

Nason-Tatum-Manteo soils are located in the eastern part of Bedford County. These soils are deep and shallow, well drained and excessively drained, gently sloping to very steep soils that have clayey or loamy subsoil. They formed in weathered sericite schist. This map unit consists of two low mountain ridges and long to narrow ridges dissected by short drainageways. Slopes range from 2 to 60 percent. Minor portions of the basin contain the Iredell-Poindexter-Mecklenburg soil association. These soils are very deep and deep, somewhat poorly drained to well drained, gently sloping to very steep soils that have a clayey or loamy subsoil. They formed in weathered hornblende, hornblende gneiss, greenstone, or diabase. Slopes range from 2 to 60 percent (SCS, 1989).

The majority of the Campbell County portion of the BOR basin has approximately equal areas of three soil associations delineated as Cullen-Wilkes, Tatum-Manteo-Nason, and Cecil Appling. Minor portions of the basin are delineated as Madison-Tallapoosa and Georgeville-Tatum soil associations (SCS, 1977). Cullen-Wilkes soils are deep and moderately deep, well drained, gently sloping to steep soils that have dominantly clayey subsoil. They formed in weathered greenstone, hornblende gneiss, diorite, and mica schist (SCS, 1977). Tatum-Manteo-Nason soils are deep and shallow, well drained and somewhat excessively drained, gently sloping to steep soils that have dominantly clayey or loamy subsoil. They formed in quartz sericite schist and sericite schist. Cecil-Appling soils are deep, well drained, gently sloping to moderately steep soils that have dominantly firm clayey subsoil. They formed in granite gneiss, quartz schist, quartzite, and granite. All of these soil associations are on broad ridges, side slopes, and narrow flood plains. On broad ridges the slopes are dominantly 2 to 15 percent, with side slopes ranging from 6 to 25 percent. Near the larger drainageways and streams, the ridges are narrower and the side slopes are steeper, commonly 15 to 60 percent. On narrow flood plains, which are along the larger streams, the slope is dominantly 0 to 6 percent (SCS, 1977). The remaining minor soil associations, Madison-Tallapoosa and Georgeville-Tatum, are deep and moderately deep, well drained gently sloping to steep soils that have dominantly clayey or loamy subsoil. They formed in sericite schist, mica schist, and quartz mica schist (SCS, 1977).

2.5.3 Climate

The climate of the watershed is characterized based on the meteorological observations made by the National Weather Service's cooperative observer at Lynchburg Regional Airport. The BOR basin is located just east of the Blue Ridge Mountains. Summers are warm, winters are not unduly severe, and rainfall is normally adequate for crop production (SCS, 1989). Although the area is near the typical path of winter storms, the Appalachian Mountains to the west lessen storm intensity (SCS, 1989). Average annual precipitation is 40.9 inches with 54% of the precipitation occurring during the crop-growing season (May-October) (SERCC, 2000). Average annual snowfall is 21.8 inches with the highest snowfall occurring during February (SERCC, 2000). Average annual daily temperature is 55.9°F with average minimum and maximum daily temperature of 45.4°F and 66.4°F, respectively. The highest average daily temperature of 86.0°F occurs in July while the lowest average daily temperature of 24.9°F occurs in January (SERCC, 2000).

2.5.4 Land use

Using remotely-sensed data, specifically, Carterra imagery consisting of 1996, 1997, and 1998 five-meter resolution panchromatic Indian Remote Sensing – 1C (IRS-1C) satellite images fused with 1997 Landsat 5 thirty-meter resolution color infrared satellite imagery, VADCR developed a digital land use coverage and identified 24 land use types in the BOR basin. The 24 land use types were consolidated into seven categories based on similarities in hydrologic and waste application/production features for the purpose of modeling (Table 2.2). Hydrologic similarity was defined in terms of percent perviousness (imperviousness). Similarity in waste application/production was determined based on potential sources of fecal coliform that could be expected to be present on the land use.

Forest lands comprise about 59% of the total watershed area (Table 2.3) and are more dominant in the upper and lower parts of the basin. Forest land, as the percentage of the total area of each watershed, ranges from 41% in Machine Creek watershed (L26a) to 73% in the Lower Big Otter River watershed (L28). The next prominent type of land use in BOR basin is pasture, which accounts for about 28% of the total basin area. Pasture, as percentage of total area, ranges from 15% in the Flat Creek watershed (L29) to 45% in the Machine Creek watershed (L26a). Table 2.3 shows each watershed area and the percentage in each land use category.

Table 2.2. Land use information for the Big Otter River basin

TMDL Land Use Categories	Pervious/Impervious (Percentage)	VADCR Land Use Categories (Class No.)
Commercial/ Industrial	Pervious (20%) Impervious (80%)	Barren (7) Industrial (13) Transportation, Communications, Utilities (14) Industrial and Commercial Complexes (15)
Cropland	Pervious (100%)	Cropland (211) Rotational Hay (2114)
Forest	Pervious (100%)	Forest (4) Water (5) Wetlands (6) Harvested Forest (44) Managed Grassland (2431) Unmanaged Grassland/CRP (2432)
High Density Residential	Pervious (80%) Impervious (20%)	Mixed Urban and Built up Land (16) Other Urban or Built up Land (17) Medium Density Residential (112) High Density Residential (113) Mobile Home Park (115)
Pasture	Pervious (100%)	Improved Pasture/Permanent Hay (2121) Unimproved Pasture (2122) Overgrazed Pasture (2123)
Rural Residential	Pervious (95%) Impervious (5%)	Open Urban Land (18) Low Density Residential (111) Wooded Residential (118) Farmstead (241)

[a] Percent perviousness/imperviousness information was used in modeling (Chapter 3)

Table 2.3. Watershed area and percentage of each land use category for the Big Otter River basin

Watershed	Total area (acres)	Percentage of total area					
		Commercial/ Industrial	Cropland	Forest	High Density Residential	Pasture	Rural Residential
Sheep Creek (L23)	34,736	0	2	67	1	25	5
North Otter Creek(L24)	32,396	0	2	71	0	24	3
Elk Creek (L25)	42,880	1	1	50	2	33	13
Machine Creek (L26a)	18,294	0	6	41	2	45	6
Little Otter River (L26b)	26,065	1	2	42	12	36	7
Buffalo Creek (L27)	44,621	1	2	55	8	27	8
Big Otter River (L28)	27,645	1	2	72	3	19	3
Flat Creek (L29)	21,585	5	0	67	6	15	7
Total	**248,222**	**1**	**2**	**59**	**4**	**28**	**7**

2.6 Source Assessment of Fecal Coliform

Potential fecal coliform sources in the watersheds of the BOR basin include both point and nonpoint sources. Since the point source dischargers are permitted, fecal coliform loadings from such sources were calculated based on the Virginia Pollution Discharge Elimination System (VPDES) permits issued by VADEQ to the dischargers. Nonpoint sources of fecal coliform were assessed using multiple approaches, including information from the Peaks of Otter and Robert E. Lee Soil and Water Conservation Districts (SWCD), VADEQ, VADCR, Virginia Department of Game and Inland Fisheries (VADGIF), Virginia Cooperative Extension (VCE), public participation, survey of producers, watershed reconnaissance and monitoring, published information, and best professional judgment. Procedures and assumptions used in estimating fecal coliform loadings from potential point and nonpoint sources of fecal coliform are described in detail in the following sections.

2.6.1 Point Sources

Fecal coliform loadings from point sources such as sewage treatment plants, schools, commercial enterprises, and food processing industries were estimated based on the VPDES permits issued to such sources. Based on the locations of the dischargers, point source fecal coliform loadings were assigned to subwatersheds within each watershed of the BOR basin. Locations of point source dischargers in the BOR basin are shown in Figure 2.3. Detailed information on point source dischargers for the individual watersheds is provided in Chapters 4 through 8.

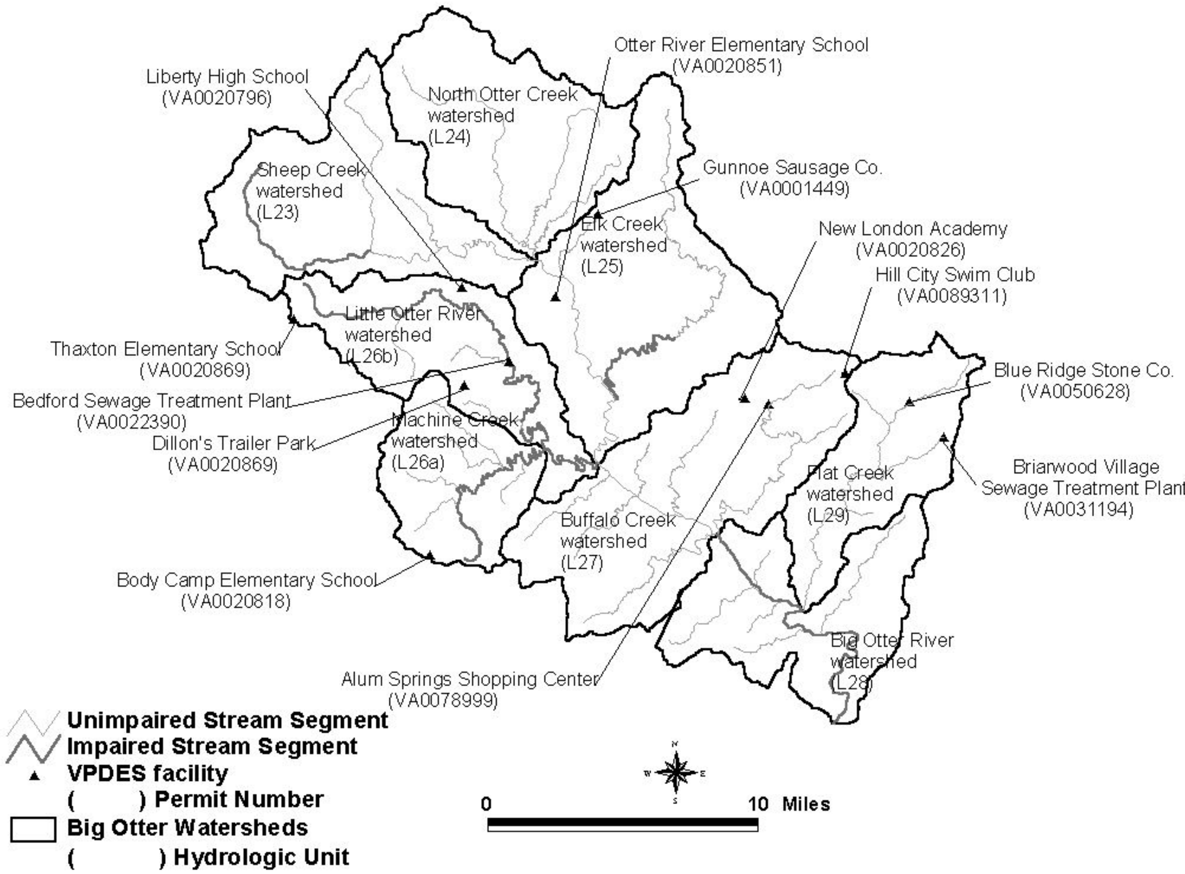

Figure 2.3. Location of point source dischargers within the Big Otter River basin

2.6.2 Nonpoint Sources

Nonpoint sources of fecal coliform include contributions from humans living in unsewered households, pets, livestock, and wildlife. Fecal coliform amounts produced by different nonpoint sources are listed in Table 2.4. Procedures and assumptions used in estimating loadings from the individual nonpoint sources are described in the following sections.

Table 2.4. Daily fecal coliform production by different sources

Source	Daily production ($\times 10^6$ cfu/day)
Human	1,950[a]
Pet	450[b]
Horse	420[c]
Beef cattle	33,000[d]
Dairy cattle	
Milk or dry cow	25,200[d]
Heifer [e]	11,592[d]
Sheep	27,000 [d]
Deer	347[f]
Raccoon	113[f]
Muskrat	25[f]
Beaver	0.2[g]
Goose	799[f]
Duck	2,430[c]
Mallard	2,430[c]
Wild Turkey	93[c]

[a] Source: Geldreich (1978)

[b] For dog, as reported by Weiskel et al. (1996)

[c] Source: ASAE (1998)

[d] Based on data presented by Metcalf and Eddy (1979) and ASAE (1998)

[e] Assumed to weigh and produce 46% less fecal coliform than a milk cow (MWPS, 1993); also includes calf

[f] Source: Yagow (1999)

[g] Source: MapTech, Inc. (2000)

Humans

The BOR basin has a total population of 39,285 people according to the 1990 census data. Distribution of human population among the watersheds is given in Table 2.5. Fecal coliform from humans can be transported to streams from failing septic systems, land-applied biosolids, or via straight pipes discharging directly into streams.

Table 2.5. Distribution of human and pet populations

Watershed	Human population	Pet population[a]
Sheep Creek (L23)	2,283	913
North Otter Creek (L24)[b]	1,343	537
Elk Creek (L25)	6,158	2,463
Machine Creek (L26a)	2,303	921
Little Otter River (L26b)	10,910	4,364
Buffalo Creek (L27)[b]	9,720	3,888
Big Otter River (L28)	2,458	983
Flat Creek (L29)[b]	4,110	1,644
Total	**39,285**	**15,713**

[a] Assumed an average of one pet per household

[b] Unimpaired watershed

Failing Septic Systems

Septic system failure is manifested by the rise of effluent to the soil surface. Runoff can transport the effluent on the surface containing fecal coliform to receiving waters. County maps were used to identify sewered service areas in the basin, which were classified as high-density residential Land use. There were 3,211 houses connected to the sewer system. Locations of the 12,502 unsewered households (with septic systems) were identified using 1999 E-911 digital data (see Glossary) (Bedford Co. Planning Dept., 1999), and assigned to the rural residential Land use. Each unsewered household was classified into one of three age categories (pre-1967, 1967-1985, and post-1985) based on USGS 7.5-min. topographic maps which were initially created using 1967 photographs and were photo-revised in 1985. Professional judgment (R.B. Reneau, personal communication, 3 December 1999, Blacksburg, Va.) was used in assigning the septic system failure rates for houses in the pre-1967, 1967-1985, and post-1985 age categories of 40%, 20%, and 3%, respectively. Estimates of these failure rates were also supported by Canter and Knox (1985) who reported failure rates as high as 40%.

Daily total fecal coliform load to the land from a failing septic system was determined by multiplying the average occupancy rate for the watershed (2.5 persons, 1990 Census) by the per capita fecal coliform production rate of 1.95×10^9 cfu/day (Geldreich, 1978). Hence, the total fecal coliform loading to the land from a typical failing septic system was 4.88×10^9 cfu/day, and some portion of these fecal coliform may be transported to a stream by runoff. The number of failing septic systems in the watersheds of the Big Otter River basin is given in Table 2.6. No reductions in fecal coliform concentration due to effluent from failing septic systems moving through the soil were considered. Because septic tanks retain influent for only 24 hours, it was assumed that die-off in the septic tank was negligible and that the effluent immediately flowed to the surface where it contributed to the amount of fecal coliform available for transport by surface runoff. There is no general consensus as to how to simulate the failure of septic systems and we chose to be conservative and assumed that failing septic systems provide no-treatment.

Table 2.6. Estimated number of unsewered households by age, number of failing septic systems, and straight pipes in the Big Otter River basin.

Watershed	Unsewered houses by age (no.)			Failing septic systems (no.)	Straight pipes
	Pre-1967	1967-1985	Post-1985		
Sheep Creek (L23)	446	14	453	194	8
North Otter Creek (L24)[a]	274	0	258	117	4
Elk Creek (L25)	611	463	1,389	378	1
Machine Creek (L26a)	273	236	219	163	1
Little Otter River (L26b)	562	515	347	338	1
Buffalo Creek (L27)[a]	1,239	1,541	1,012	834	12
Big Otter River (L28)	537	443	3	304	1
Flat Creek (L29)[a]	698	945	0	468	1
Total	**4,640**	**4,157**	**3,686**	**2,796**	**29**

[a] Unimpaired watershed

<u>Biosolids</u>

Biosolids produced at the Roanoke Wastewater Treatment Plant were applied to cropland and pasture lands in the Little Otter River (L26a) and Machine Creek watersheds (L26b) of the BOR basin, during the study period as discussed in chapter 3. There is the potential that surface runoff can transport part of the fecal coliform in biosolids to streams. Average biosolids applications were estimated based on the monthly monitoring reports supplied to VADEQ and VDH by the contractor responsible for spreading the biosolids. Fecal coliform loading as a result of biosolids application was estimated based on the actual application rate (dry tons/acre) and a fecal coliform concentration of 101 cfu/g-biosolids (MapTech Inc., 2000). Specific loading from biosolids for each watershed is given in Chapters 6 (Machine Creek) and 7 (Little Otter River). Biosolids from the Wastewater Treatment Plant located in Union and Essex

Counties in New Jersey were land applied to 402.8 acres of Bedford County farmland between October and December 1999 at an average application rate of 4.4 dry tons per acre. These land application events occurred outside of the period considered in the TMDL for the BOR basin.

<u>Straight pipes</u>

In unsewered areas, before on-site wastewater treatment became mandatory, some households located close to streams discharged their raw sewage directly into streams through straight pipes. It is likely that some of the older houses close to streams still use straight pipes to discharge sewage directly into streams. Ten percent and 2% of the houses located within 150 ft of streams, in the pre-1967 and 1967-1985 age categories, respectively, were assumed to have straight pipes (R.B. Reneau, personal communication, 3 December 1999, Blacksburg, Va.). Based on these criteria, the estimated number of straight pipes in the constituent watersheds of the BOR basin are given in Table 2.5.

Pets

A total of 15,713 pets in the BOR basin were estimated based on the assumption of one pet for each household; pet populations in the watersheds are given in Table 2.5. Weiksel et al. (1996) estimated that a dog produced 0.45×10^9 cfu/day; this value was assumed to represent average fecal coliform production from a pet. Pet waste is generated in the rural residential and high-density residential Land use types. Fecal coliform loading to streams from pet waste can result from surface runoff transporting fecal coliform from residential areas.

Livestock

Fecal coliform in livestock waste can be directly excreted to the stream, or they can be transported to the stream by surface runoff from animal waste deposited on pastures or applied to crop and pasture lands. The major types of livestock present in the BOR basin include beef cattle, dairy cattle, horses, and sheep. Since the sheep population is very small compared with the other three livestock types, it was assumed that the contribution of fecal coliform from the sheep population is negligible. There are no commercial poultry operations within the BOR basin.

Cattle

Initial estimates of the beef and dairy cattle populations in each watershed were made by VADCR in 1996 by averaging the estimates of the populations from the 1987 and 1992 Agricultural Census and disaggregating these numbers to the hydrologic unit or watershed level. These numbers were further modified by local knowledge contributed by Soil and Water Conservation Districts (SWCD), Virginia Cooperative Extension (VCE), Natural Resources Conservation Service (NRCS), and the Farm Service Agency (FSA) personnel familiar with these areas. Watershed-level Land use maps were used to estimate pasture acreage in each watershed. Watershed-level beef and dairy populations were further refined using a producers survey and during a follow-up consultation with producers and Peaks of Otter SWCD personnel. The total beef cattle population in the BOR basin was estimated to be 14,461. Within each watershed, the beef cattle population was distributed among the subwatersheds based on pasture acreage (presented in Chapters 4 through 8). The milking herds, comprised of milk cows and dry cows, were allocated among the subwatersheds based on local knowledge (presented in Chapters 4 through 8).

Since the dairy cattle populations provided by VADCR did not include replacement heifers, the heifer populations were estimated using the current herd composition where such information was available; otherwise, based on information from VCE, it was assumed that heifers constituted half of the total dairy herd. Dry cows were assumed to constitute 16% of the milking herd. Hence, the total dairy cattle population in BOR basin was calculated to be 5,255. These numbers are applicable for time periods prior to 1996.

Producers indicated that some dairy operations have gone out of operation in the past four years. Therefore, using 1995 FSA aerial photographs, dairy operations were identified in the watersheds. The size of the dairy operations currently in operation was determined through visits to the watersheds, and in cooperation with the Peaks of Otter SWCD personnel. The dairy cattle population as determined above was used for simulating pre-1996 conditions in the watersheds; the current dairy numbers were used in the development of the allocation scenarios presented in Chapters 4 through 8. Beef and dairy cattle populations for each watershed are given in Table 2.7.

Table 2.7. Distribution of beef cattle, dairy cattle, and horses

Watershed	Beef	Dairy[a]		Horses
		Pre-1996	Current	
Sheep Creek (L23)	1,500	1,076	314	405
North Otter Creek (L24)[b]	1,630	480	0	370
Elk Creek (L25)	3,410	600	500	496
Machine Creek (L26a)	1,464	0	0	202[c]
Little Otter River (L26b)	1,697	649	605	260[c]
Buffalo Creek (L27)[b]	2,100	2,130	2,130	262[d]
Big Otter River (L28)	1,210	320	160	114[d]
Flat Creek (L29)[b]	1,400	0	0	141[e]
Total	**14,411**	**5,255**	**3,709**	**2,250**

[a] Includes milk cows, dry cows, and heifers

[b] Unimpaired watershed

[c] Combined horse population was available for Machine Creek and Little Otter River watersheds. Allocations to individual watersheds were done based on pasture acreages.

[d] Combined horse population was available for Buffalo Creek and Big Otter River watersheds. Allocations to individual watersheds were done based on pasture acreages.

[e] Estimated using the number of horses per acre in Big Otter River watershed

In the BOR basin, milk cows are confined according to the schedule given in Table 2.8 (S. Baker, VCE, Bedford Co., personal communication, 25 May 2000). When not in confinement, milk cows are kept on pastures. Beef cattle, dry cows, and heifers are kept on pastures throughout the year with minimum confinement (S. Baker, VCE, Bedford Co., personal communication, 25 May 2000). It was assumed that cattle on pastures deposit manure on pasture or directly in the stream. In order to estimate the amount of manure and, hence, fecal coliform loading to streams, the following assumptions and procedures were used.

- In addition to pastures separated from streams by other Land use types, producers indicated that off-stream watering sources were provided to cattle on very large pastures. Using GIS, pasture acreages that were not separated from streams by other Land use types and pasture acreages that were within 1640 ft (500 m) of streams were estimated. Such pastures were assumed to have stream access. Estimates of cattle access to stream were also obtained from the producer survey. However, these estimates were not representative since they were based on a small fraction of producers in the watersheds.

Table 2.8. Time spent by milk cows in confinement and by all cattle in the stream.

Month	Time spent by milk cows in confinement (hours/day)	Time spent by cattle in the stream (hours/day)
January	14.40	0.50
February	14.40	0.50
March	8.40	0.50
April	8.00	0.75
May	8.00	1.00
June	8.00	2.00
July	8.00	2.00
August	8.00	2.00
September	8.00	1.00
October	8.00	0.75
November	8.40	0.50
December	14.40	0.50

- Assuming the same cattle stocking density (cattle/acre-pasture) on pastures with and without stream access, percentage of cattle with stream access for the watersheds of the BOR basin was calculated (Table 2.9). For assessing fecal coliform loading to stream and pasture more accurately, cattle access to stream was determined for each subwatershed; results are presented in Chapters 4 through 8.

Table 2.9. Percentage of cattle with stream access

Watershed	Percentage of cattle with stream access
Sheep Creek (L23)	51
North Otter Creek (L24)[a]	66
Elk Creek (L25)	41
Machine Creek (L26a)	58
Little Otter River (L26b)	53
Buffalo Creek (L27)[a]	37
Big Otter River (L28)	50
Flat Creek (L29)[a]	46
Average	**50**

[a] Unimpaired watershed

- Cattle with stream access spend varying amounts of time in the stream during different seasons (Table 2.8) (S. Baker, VCE, Bedford Co., personal communication, 25 May 2000). In addition to seeking relief from the heat, producers reported that cattle spend more time in the stream during the three summer months to get away from face flies. Producers reported that face flies do not follow animals into the shade and since streams are usually shaded, cattle in streams were likely to be bitten less than cattle on pastures.

- Thirty percent of cattle in and around streams directly deposit fecal coliform into the stream. The remaining manure is deposited on pastures.

The time cattle spent in the streams was a function of the amount of time the animals had access to the stream. If cattle were confined for a portion of the day (dairy cattle usually were, beef generally were not) then this confinement reduced their access to the streams. The reduction in stream access due to confinement was accounted for in the calculation of direct deposited loads to streams from dairy cattle. All livestock calculations were based on estimates of livestock in each subwatershed. For each subwatershed, an analysis was done based on the number of beef and dairy cattle, confinement schedules for each type of cattle, and pasture areas with access to streams, to determine the amount of time each type of cattle spent in the streams of each subwatershed.

Manure produced in confinement by milk cows is stored for application to cropland or pasture. Based on the producer survey, it was estimated that 15% of the dairy operations had manure storage capacities of less than 30 days, 10% of the operations had storage capacities of 60 days, while the remaining operations had storage capacities of 180 days. Producers reported that stored dairy manure was applied to cropland and pasture at application rates of 8,000 and 4,000 gal/acre-year, respectively, with priority being given to cropland. Dairy manure is applied to cropland and pasture based on the monthly schedule given in Table 2.10. During June through September, manure is not applied to cropland due to the presence of a growing crop.

The primary rotation on cropland consists of corn (grain or silage) followed by a winter cover crop or fallow. Therefore, 55% (February through May) of the dairy manure is applied to the main crop while 15% (October through November) is applied to the winter cover crop. Through the survey of producers in the BOR basin, it was estimated that 60% of the cropland was under no-till while 30% was under minimum tillage; the remainder of the cropland was under conventional tillage. Since manure is applied to

Table 2.10. Schedule of dairy manure application to cropland and pasture

Month	Applied as percent of total	Land use
January	0	
February	5	Cropland
March	25	Cropland
April	20	Cropland
May	5	Cropland
June	10	Pasture
July	0	
August	5	Pasture
September	15	Pasture
October	5	Cropland
November	10	Cropland
December	0	
Total	**100**	

the surface (no incorporation) under no-till, it was assumed that all of the fecal coliform applied to the land could be removed by runoff. Minimum tillage encompasses a wide range of practices that can result in varying degrees of incorporation of the manure in the cropland. Hence, for minimum tillage, it was assumed that 25% of the manure was incorporated, resulting in 75% of the fecal coliform being available for removal by runoff. Under conventional tillage, manure may be incorporated or disked into the soil; therefore, it was assumed that only 10% of the fecal coliform applied to conventionally tilled cropland was available for removal by runoff. It was assumed that manure was surface-applied to the winter cover crop or fallow land. Similarly, it was assumed that manure applied to pasture during June through September was surface-applied.

Horses

Except for the Flat Creek watershed, horse populations in the remaining seven watersheds were obtained through local knowledge (B. Wills, Peaks of Otter SWCD, Bedford Co., personal communication, 1 June 2000). Separate horse numbers were not available for the Machine Creek and Little Otter River watersheds; therefore, based on their respective pasture acreages, horse numbers were assigned to individual watersheds. The estimated horse population in Buffalo Creek and the Lower Big Otter River watersheds combined was allocated to the two watersheds based on pasture acreage. The horse population in the Flat Creek watershed was estimated using the average animal density (horses/acre-pasture) in the Lower Big Otter River watershed and the pasture acreage in the Flat Creek watershed. The estimated horse population in the BOR basin was 2,250. The horse populations for each watershed are given in Table 2.7.

It was assumed that horses are not confined at any time during the year. Thus, all horse manure and fecal coliform loading was directly deposited on pastures. It was assumed that there was no direct fecal coliform loading to the stream from horses.

Wildlife

Wildlife fecal coliform contributions can be from excretion of waste on land and from excretion directly into streams. Based on information provided by VADGIF (G. Costanzo, M. Knox, Randy Farrar, VADGIF, personal communication, May 2000) and producers, wildlife species that were found in quantifiable numbers in the watershed included deer, raccoon, muskrat, beaver, goose, mallard, wood duck, and wild turkey. For each watershed in the BOR basin, the population of each species was estimated based on acres of suitable habitat and population density per unit area of habitat (Table 2.11). Suitable habitat descriptions and population density of the wildlife species used in the TMDL study for the South Fork of the Blackwater River (MapTech Inc., 2000), located about 15 miles from the basin, were used in this study. Based on best professional judgment and consultation with VADGIF personnel, percent direct deposition in the stream by the wildlife species was estimated (Table 2.11). Distribution of wildlife among the watersheds was based on habitat acreage for the wildlife species in a watershed. Similarly, distribution of wildlife among the subwatersheds of each watershed was based on wildlife habitat acreage in the subwatershed and is presented in Chapters 4 through 8.Table 2.11, which lists wildlife population density, habitat description and acreage, and percent direct fecal deposition in streams

Table 2.11 Wildlife habitat and percentage of direct deposition.

Wildlife type	Population density (animal /ac-habitat)	Habitat	Direct fecal deposition in streams (%)
Deer	0.0470	Entire watershed	1
Raccoon	0.0700	Within 600 ft of streams and ponds	10
Muskrat	2.7500	Within 66 ft of streams and ponds	50
Beaver	4.8000	Within 300 ft of streams and ponds	90
Goose	0.0040	Within 66 ft of streams and ponds	25
Mallard	0.0020	Within 66 ft of streams and ponds	25
Wood duck	0.0018	Within 66 ft of streams and ponds	25
Wild Turkey	0.0100	Entire watershed excluding farmstead and urban land uses	1

Table 2.12. Distribution of wildlife population among the watersheds

Watershed	Deer	Raccoon	Muskrat	Beaver	Goose	Wood duck	Mallard	Wild Turkey
Sheep Creek (L23)	1,634	299	1,394	147	138	62	70	235
North Otter Creek (L24)	1,524	266	1,327	131	130	58	65	229
Elk Creek (L25)	2,013	363	1,912	192	173	76	85	212
Machine Creek (L26a)	854	265	1,359	135	74	33	37	75
Little Otter Creek (L26b)	1,225	337	1,747	173	105	49	52	110
Buffalo Creek (L27)	2,099	486	2,466	246	180	81	90	246
Lower Big Otter River (L28)	1,300	321	1,492	156	109	50	54	202
Flat Creek (L29)	1,014	218	1,057	94	87	40	43	145
Total	**11,663**	**2,555**	**12,754**	**1,274**	**996**	**449**	**496**	**1,454**

2.6.3 Summary

Fecal coliform loading to streams comes from both point and nonpoint sources. Direct nonpoint source loading to streams is comprised of direct fecal coliform loading by beef and dairy cattle, wildlife and straight pipes. Portions of the fecal coliforms in land-applied waste (animal waste, septic system effluent, and biosolids) as well as livestock and wildlife waste deposited on land could also be transported into streams by runoff. Fecal coliform loading on cropland comes from application of stored dairy waste and biosolids as well as direct deposition by wildlife. Direct deposition by cattle and wildlife as well as dairy manure and biosolids application contribute to loading on pastures. Fecal coliform die-off during storage should be taken into account while estimating fecal coliform loadings to cropland and pasture from applied dairy manure. Fecal coliform contributions to forests are due to wildlife deposits. Fecal coliform loading on rural residential land use is comprised of effluent from failing septic systems, wildlife, and pet waste. Pet waste and wildlife are the sole sources of fecal coliform loading to the high-density residential land use since the houses in this land use were assumed connected to properly functioning sewer systems. Fecal coliform loading to the commercial/industrial land use type may result from bird and rodent droppings as well as occasional pet and wildlife deposits. In this study, fecal coliform loading to the commercial/industrial land use is 10.3×10^6 cfu/acre-day (USEPA, 2000).

The amount of fecal coliform produced by a source is not sufficient to draw conclusions regarding fecal coliform contributions to receiving waters. The potential for a fecal coliform source to contaminate receiving waters also depends on factors such as where the waste is generated, how it is stored/handled, and how it is transported to the waterbody. For example, even though the watershed has a sizeable human population, fecal coliform from sewered areas and well-maintained septic systems is unlikely to reach waterbodies in large amounts. Hence, factors such as storage, environmental conditions, attenuation, and proximity to streams are considered in estimating fecal coliform loadings to streams.

Assumptions and quantities (e.g., livestock numbers) discussed in this section were used in calculating fecal coliform loads to each watershed in the BOR basin. Each watershed was further divided into a number of subwatersheds to take into account the presence of local features that could affect the hydrology and fecal coliform loading (e.g., location of dairy operations). Hence, the assumptions that were applied in estimating fecal coliform loads in the watershed were also applied in distributing the load among the different subwatersheds

3 MODELING PROCESS FOR TMDL DEVELOPMENT

A key component in developing a TMDL is establishing the relationship between pollutant loadings (both point and nonpoint) and in-stream water quality conditions. Once this relationship is developed, management options for reducing pollutant loadings to streams can be assessed. In developing a TMDL, it is critical to understand the processes that affect the fate and transport of the pollutant that cause the impairment of the waterbody of concern. Pollutant transport to water bodies is evaluated using a variety of tools, including monitoring, GIS, and computer simulation models. In this chapter, model description, input data requirements, model calibration procedure and results, and model validation results are discussed.

3.1 Model Description

Development of a TMDL requires the use of a watershed-based model that integrates both point and nonpoint sources and simulates in-stream water quality processes. The HSPF watershed model (Bicknell et al., 1993) was used to model fecal coliform transport and fate in the BOR basin. The BASINS interface (Better Assessment Science Integrating Point and Nonpoint Sources System) Version 2.0 (Lahlou et al., 1998) was used to facilitate use of HSPF. Specifically, the NPSM interface within BASINS provides pre- and post-processing support for HSPF. The ArcView 3.0a or 3.1 GIS provides the integrating framework for BASINS and allows the display and analysis of landscape information.

The HSPF model simulates nonpoint source runoff and pollutant loadings, performs flow routing through streams, and simulates in-stream water quality processes (Donigian et al., 1995). HSPF estimates runoff from both pervious and impervious parts of the watershed and stream flow in the channel network. The sub-module PWATER within the module PERLND simulates the water budget on pervious areas (e.g., agricultural land). Surface runoff from impervious areas is modeled using the IWATER sub-module within the IMPLND module. Simulation of flow through the stream network is performed using the sub-modules HYDR and ADCALC within the module RCHRES. While HYDR routes the water through the stream network, ADCALC calculates variables used for simulating convective transport of the pollutant in the stream. Fate of fecal coliform on pervious and impervious land segments is simulated using the PQUAL (PERLND module) and

IQUAL (IMPLND module) sub-modules, respectively. Fate of fecal coliform in stream water is simulated using the GQUAL sub-module within the RCHRES module.

3.2 Selection of Subwatersheds

The entire BOR basin is a relatively large watershed (388 mi^2); so modeling of the constituent watersheds was conducted in phases. The BOR basin is subdivided into seven subwatersheds as defined in Virginia's HU system. The HUs in the BOR basin are Sheep Creek (L23), North Otter Creek (L24), Elk Creek (L25), Machine Creek (L26a), Little Otter River (L26b), Buffalo Creek (L27), Flat Creek (L29), and the Lower Big Otter River (L28), which is the HU at the outlet of the BOR basin. Each of the HU were subdivided further to account for the spatial variation of fecal coliform sources, since loadings of fecal coliform are believed to be associated with the type of land use activities and degree of development in a watershed. The stream networks for each watershed were delineated based on the blue lines on USGS topographic maps. The number of subwatersheds in each watershed and additional information can be found in Chapters 4 through 8. In the first phase of the modeling, the headwater watersheds were modeled. In the subsequent phases, downstream watersheds were modeled. The general order of the modeling was Sheep, North Otter, Machine, and Flat Creeks, followed by the Little Otter River and Elk Creek, then Buffalo Creek, and finally, the Big Otter River itself. Contributions from upstream watershed were incorporated as inflows (or MUTSIN files with an time-step of an hour) to the downstream watershed simulations.

3.3 Input Data Requirements

The HSPF model requires a wide variety of input data to describe hydrology, water quality, and land use characteristics of the watershed. The different types and sources of input data used to develop the TMDLs are discussed in the following sections.

3.3.1 Climatologic Data

Required weather data were obtained from the weather station closest to the watershed. Hourly precipitation, solar radiation, and temperature data were obtained from the National Climatic Data Center's (NCDC) weather station at the Lynchburg airport, which is located in the eastern portion of the BOR basin. Additional hourly rainfall data were obtained from the NCDC gage in Altavista, Virginia. Also, daily rainfall measurements were obtained from a National Weather Service (NWS) gage in Bedford, Virginia and was used to supplement the data from Lynchburg and Altavista. Detailed descriptions of the weather data and the procedure for converting the raw data into the required data set are included in Appendix B.

3.3.2 Hydrology Model Parameters

The hydrology parameters required by PWATER and IWATER were defined for each land use category for each subwatershed. For each stream reach, a function table (FTABLE) is required to describe the relationship between water depth, surface area, volume, and discharge (Donigian et al., 1995). These parameters were estimated by surveying representative channel cross-sections in each subwatershed. Hydrology parameters required for the PWATER, IWATER, HYDR, and ADCALC sub-modules are listed in Appendix B.1 of BASINS ver. 2.0 User's Manual (Lahlou et al., 1998). Parameters required as inputs for PQUAL, IQUAL, and GQUAL are given in Appendix B.1 of BASINS ver. 2.0 User's Manual (Lahlou et al., 1998). Values for the parameters were estimated for local conditions and improved through calibration.

3.3.3 Land use

The land use categories were assigned pervious/impervious percentages, which allowed a land use with both pervious and impervious fractions to be modeled using both the PERLND and IMPLND modules. Land use data were used to select several hydrology and water quality parameters for the simulations.

3.4 Accounting for Fecal Coliform Sources

3.4.1 Overview

There are 14 VADEQ permitted point source discharges in the BOR basin. The simulation process as it pertains to permitted discharges was based on instructions from VADEQ and was undertaken in the following manner. For existing condition runs, the permitted point source dischargers were assumed to not discharge fecal coliforms due to chlorination. Only the flow from the dischargers at their permitted flow rate was included in the existing condition runs. For the allocation runs, the permitted dischargers were assumed to discharge their permitted (200 cfu/100mL) concentrations and flow rates.

Fecal coliform loads that are directly deposited by cattle and wildlife in streams were treated as point sources and are referred to as "direct nonpoint sources". Fecal coliform that is land-applied or deposited on land was treated as a nonpoint source loading and all or part of that load was susceptible to transport to receiving waters as a result of surface runoff during rainfall events. Direct nonpoint source loading was applied to the stream reach in each subwatershed as appropriate.

The nonpoint source loading was applied as fecal coliform counts to respective land use category in a subwatershed on a daily basis. Fecal coliform was considered to die-off in land-applied sources, stored manure, and in the stream. Both direct nonpoint and nonpoint source loadings were varied by month to account for seasonal differences.

3.4.2 Modeling Fecal Coliform Die-Off

Fecal coliform die-off was modeled using a first order die-off equation of the form:

$$C_t = C_0 10^{-Kt} \qquad [3\text{-}1]$$

where: C_t = concentration or load at time t, C_0 = starting concentration or load, K = decay rate (day^{-1}), and t = time in days. A review of literature provided estimates of decay rates applicable to waste storage and handling (Table 3.1).

Table 3.1. First order decay rates for different types of animal waste storage as affected by storage conditions and their sources

Waste type	Storage	Decay rate, day^{-1}	Reference
Dairy manure	Pile (not covered)	0.066	Jones (1971)[a]
	Pile (covered)	0.028	
Beef manure	Anaerobic lagoon	0.375	Coles (1973)[a]

[a] Cited in Crane and Moore (1986)

Based on the values cited in the literature, the following decay rates were used in simulating fecal coliform die-off in stored waste.

- Liquid dairy manure: Since the decay rate for liquid dairy manure storage could not be found in the literature, the decay rate for beef manure in anaerobic lagoons (0.375 day^{-1}) was used assuming that the storage creates anaerobic conditions.

- Solid cattle manure: Based on the range of decay rates (0.028-0.066 day^{-1}) reported for solid dairy manure, a decay rate of 0.05 day^{-1} was used assuming that a majority of manure piles are not covered.

The procedure for calculating fecal coliform counts in waste at the time of land application is included in Appendix C. A decay rate of 0.045 day^{-1} was assumed for fecal coliform on the land surface. The decay rate of 0.045 day^{-1} is represented in HSPF by specifying a maximum surface buildup (SQOLIM), which is a multiple of the daily loading rate. An in-stream decay rate (FSTDEC) of 1.15 day^{-1} (USEPA, 1985) was used.

3.4.3 Modeling Nonpoint Sources

For modeling purposes, nonpoint fecal coliform loads were those that were deposited or applied to land and, hence, required surface runoff events for transport to streams. Fecal coliform loading (cfu/month) by land use for all sources in each TMDL watershed is presented in Chapters 4 through 8. The existing condition fecal coliform loads are based on our best estimates of existing wildlife, livestock, and human populations and fecal coliform production rates presented in Chapter 2. Simulations of future conditions used in the TMDL allocation plan and the phase 1 implementation plan used the same wildlife and human populations and resulting loads, however, dairy cattle numbers were reduced to reflect the continuing decline in dairy operations within the BOR basin as described in Chapter 2. Fecal coliform in stored waste was adjusted for die-off prior to the time of land application when calculating loadings to cropland and pasture. For a given period of storage, the total amount of fecal coliform present in the stored manure was adjusted for die-off on a daily basis. Fecal coliform loadings to each subwatershed in each TMDL watershed are presented in Appendix D. The sources of fecal coliform to different land use categories and how they were handled by the model are briefly discussed below.

1 Cropland: Liquid dairy manure and solid manure are applied to cropland as described in Chapter 2. Fecal coliform loadings to cropland were adjusted to account for die-off during storage and partial incorporation during land-application. For modeling, monthly fecal coliform loading assigned to cropland was distributed over the entire cropland acreage within a subwatershed. Thus, loading rate varied by month and subwatershed.

2 Pasture: In addition to direct deposition from cattle and wildlife, pastures receive applications of liquid dairy manure and solid manure as described in Chapter 2. Applied fecal coliform loading to pasture was reduced to account for die-off during storage. For modeling, monthly fecal coliform loading assigned to pasture was distributed over the entire pasture acreage within a subwatershed.

3 Rural Residential: Fecal coliform loading on rural residential land use came from failing septic systems, wildlife and waste from pets. In the model simulations, fecal coliform loads produced by failing septic systems and pets in a subwatershed were combined and assumed to be uniformly applied to the rural residential land use areas.

4 High-Density Residential: These areas were sewered and fecal coliform loading was produced by pets and wildlife. The fecal coliform load was applied uniformly over the entire high-density residential acreage.

5 Commercial/Industrial: Fecal coliform loading to the commercial/industrial land use was assumed to be a constant 10.3×10^6 cfu/day (USEPA, 2000)

6 Forest: Wildlife not defecating in streams and pastures provided fecal coliform loading to the forested land use. Fecal coliform, except for the percentage considered as direct load to the stream, was applied uniformly over the forest areas.

3.4.4 Modeling Direct Nonpoint Sources

Fecal coliform loads from direct nonpoint sources included cattle in streams, wildlife in streams, and direct loading to streams from straight pipes from residences that might be present. Loads from direct nonpoint sources in each subwatershed are described in detail in Chapters 4 through 8.

3.5 Model Calibration and Validation

Model calibration is the process of selecting model parameters that provide an accurate representation of the watershed. Validation ensures that the calibrated parameters are appropriate for time periods other than the calibration period. In this section, the procedures followed for calibrating the main hydrology components of the HSPF model are discussed. The procedures followed for calibrating the water quality components of HSPF are discussed in Chapters 4 through 8. The calibration and validation results for the hydrology component are presented in the following sections.

3.5.1 Hydrology

For the hydrologic component of the HSPF calibration, observed values for daily stream flow are required. Daily discharge observations are available from two USGS flow-monitoring stations at two locations in the BOR basin. The USGS station north of Altavista, Virginia (Station Number 02061500) is located near the bridge on State Route 682 over the BOR (Figure 3.1). The drainage area monitored at this station is 320 square miles (204,866 acres) and the available period of record is April 1937 through September 1999. The other USGS station is located near the City of Bedford, Virginia (Station Number 02061000). The drainage area monitored at station 02061000 is 116 square miles (74,264 acres) and the available period of record is October 1943 through September 1960. The locations of the USGS stations and the contributing watersheds are shown in Figure 3.1.

In order to provide additional flow data for assessing the accuracy of the model simulations, a regression relationship was developed so that flow at the upper station could be generated from flows at the lower gaging station. The regression was used to provide an estimate of flow at USGS station 02061000 during the calibration and validation periods. The additional data at this station allowed for the assessment of the calibrated input parameters for a smaller watershed. The regression was performed using the REG procedure in SAS (1996). The model used for the regression was a simple linear relationship ($y = m*x + b$) with the flow observations from USGS station 02061500 being the independent variable (x) and the observations from USGS station 02061000 being the dependent variable (y). For the regression, the intercept (b) was set to zero. Initially, two separate regressions were done for the periods of 10/1/1943 to 9/30/1950 (Period 1) and 10/1/1950 to 9/30/1960 (Period 2). The regressions done for the two periods were used to assess if there were in any changes in the responses of either watershed during the full period (10/1/1943 to 9/30/1960). The regression results are listed in Table 3.2. The 5% difference in the slope estimates for Periods 1 and 2 was considered insignificant.

Table 3.2. Regression Results for Flow Data Estimation.

Period	Slope Estimate	r^2
Period 1	0.363	0.894
Period 2	0.383	0.872
Entire Period	0.373	0.882

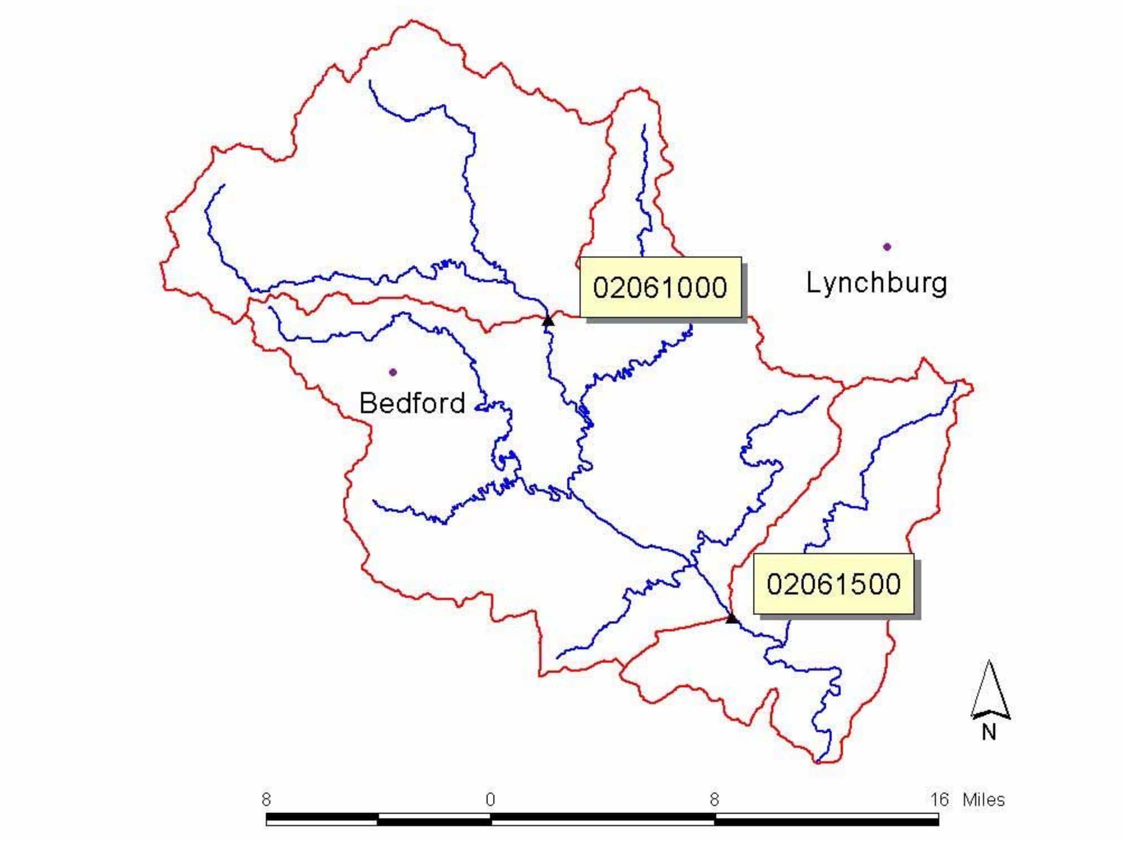

Figure 3.1. Locations of USGS stations and contributing watersheds.

The overall quality of the regression between the flows at the two stations for the entire time-period (10/1/1943 through 9/30/1960) was reasonable (Table 3.2). The high r^2 value (0.882) for the regression indicated that there is a strong linear relationship between the flows at the two stations. Furthermore, the significance of the slope coefficient was very high with a p-value less than 0.001. The quality of regression was considered sufficient to be used to estimate flow values for USGS station 02061000 during the calibration and validation periods.

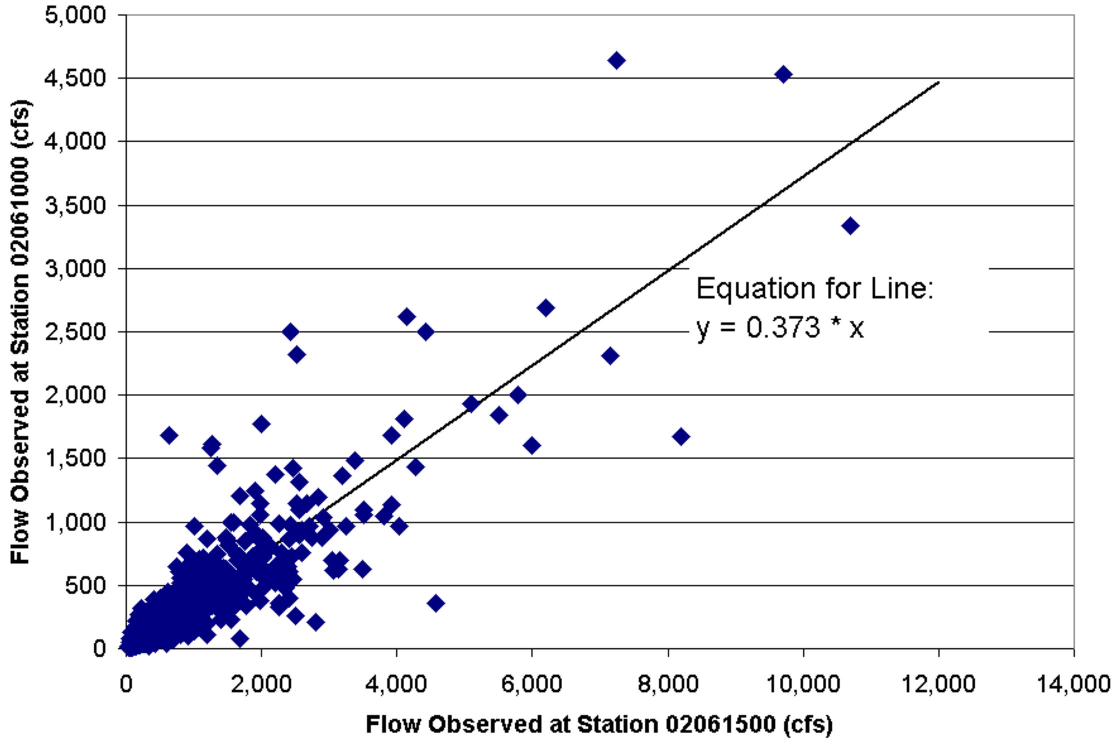

Figure 3.2. Observed and Estimated Flows for Regression Between USGS Stations 02061000 and 02061500.

Several precipitation gages and weather stations were used in the calibration and validation simulations. The locations of the gages and stations relative to the BOR basin are shown in Figure 3.3. The National Climatic Data Center's(NCDC) hourly precipitation gages at Lynchburg Municipal Airport and at Altavisa (Figure 3.3) were the main gages used for model calibration and the NCDC daily precipitation data at Bedford were used to verify and supplement the data from the other gages. The surface data, such as air temperature, wind speed, relative humidity and so on, from the meteorological station at Lynchburg Municipal Airport was used for the entire watershed.

The hydrologic calibration was performed using the flow data from USGS station 02061500. Additional validation runs were conducted using the estimated flow data from station 02061000. The calibration period selected was January 1, 1990 to May 31, 1995, and the validation period was January 1, 1996 to December 31, 1998. The additional validation runs using the estimated flow data from USGS station 02061000 provided a measure of the transferability of the calibrated data set from the larger watershed to smaller subwatersheds.

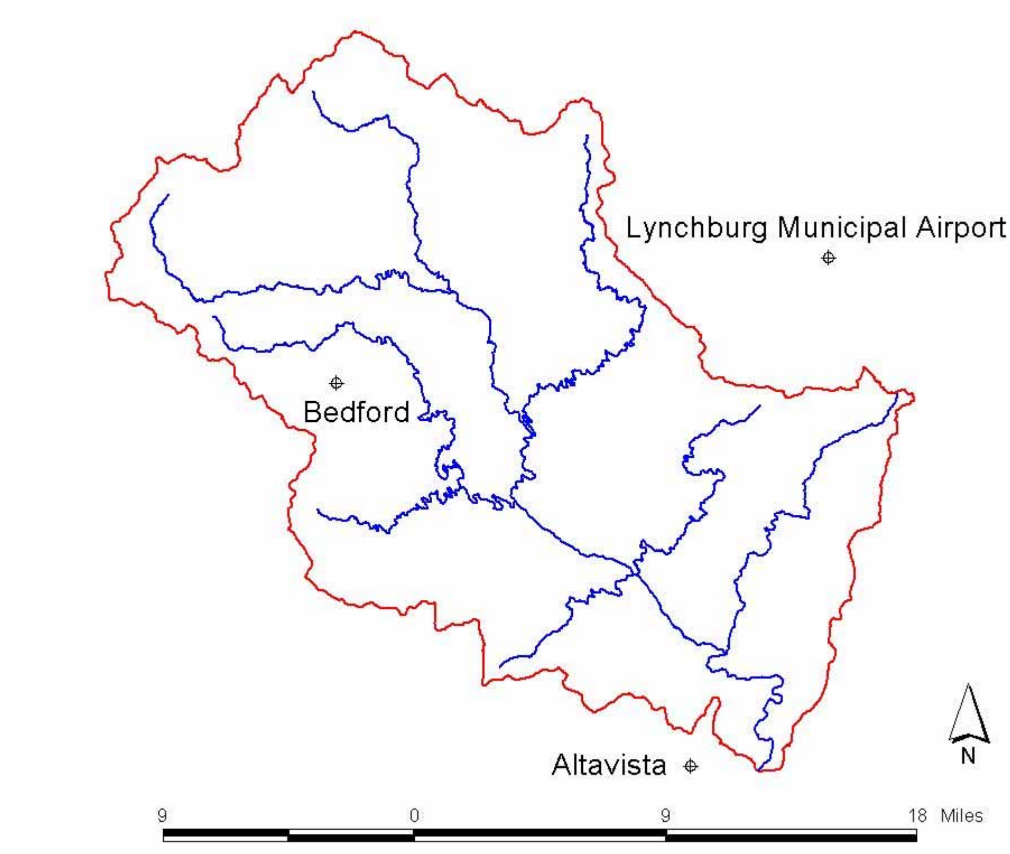

Figure 3.3. Locations of Precipitation Gages and Weather Station.

The HSPEXP decision support software (Lumb and Kittle, 1993) was used to develop a calibrated HSPF data set for the BOR basin. The HSPEXP system provides guidance on parameter adjustment during the calibration process. This guidance is provided through a decision support system that is based on the experience of expert modelers in applying HSPF to various types of watersheds (Lumb and Kittle, 1993). The accuracy of HSPF simulation results is measured in HSPEXP by comparing simulated and observed daily discharge values. Comparison of simulated and observed data is conducted for several parameters including annual water balances, seasonal variability, storm events, and for the overall time series. The HSPEXP software requires the user to identify a set of storms to investigate the accuracy of the simulated storm response during each season. Guidance for storm selection is given in the HSPEXP user manual (Lumb and Kittle, 1993). For the calibration period, 15 storm events were selected. For the validation period, 12 storm events were selected. Values for parameters that represent the different levels of accuracy are calculated for both the simulated and observed data and compared as a percent error in HSPEXP. The guidance provided by HSPEXP is based on the percent error between the various observed and simulated values for each parameter (Lumb and Kittle, 1993). The default criteria recommended in HSPEXP were used in the calibration and are listed in Table 3.3. These same criteria were used in the validation of the model at USGS station 02061500, but less stringent criteria were used for validation runs at USGS station 02061000. The criteria used for the validation runs at USGS station 02061000 were two times the criteria listed in Table 3.3. These more relaxed criteria are due to the flow data at station 02061000 for the validation period being estimated.

Table 3.3. Calibration criteria used in HSPEXP for hydrologic calibration

Variable	Percent Error Criteria
Total Volume	10%
Low Flow Recession	0.010%
50% Lowest Flows	10%
10 % Highest Flows	15%
Storm Peaks	15%
Seasonal Volume Error	10%
Summer Storm Volume Error	15%

A comparison of the simulated and observed stream flow data is given for USGS Station 02061500 in Table 3.4 for the calibration period of January 1, 1990 to May 31, 1995. There was very good agreement between the observed and simulated stream flow, indicating that the model represented the hydrologic characteristics of the watershed very well. Percent error for each variable in Table 3.4 is within the criteria specified. In Figure 3.4, the simulated and observed stream flow for a shorter period within the calibration period is shown. The simulated data follow the pattern of the observed data very well. The model closely simulates both base flow conditions and storm peaks.

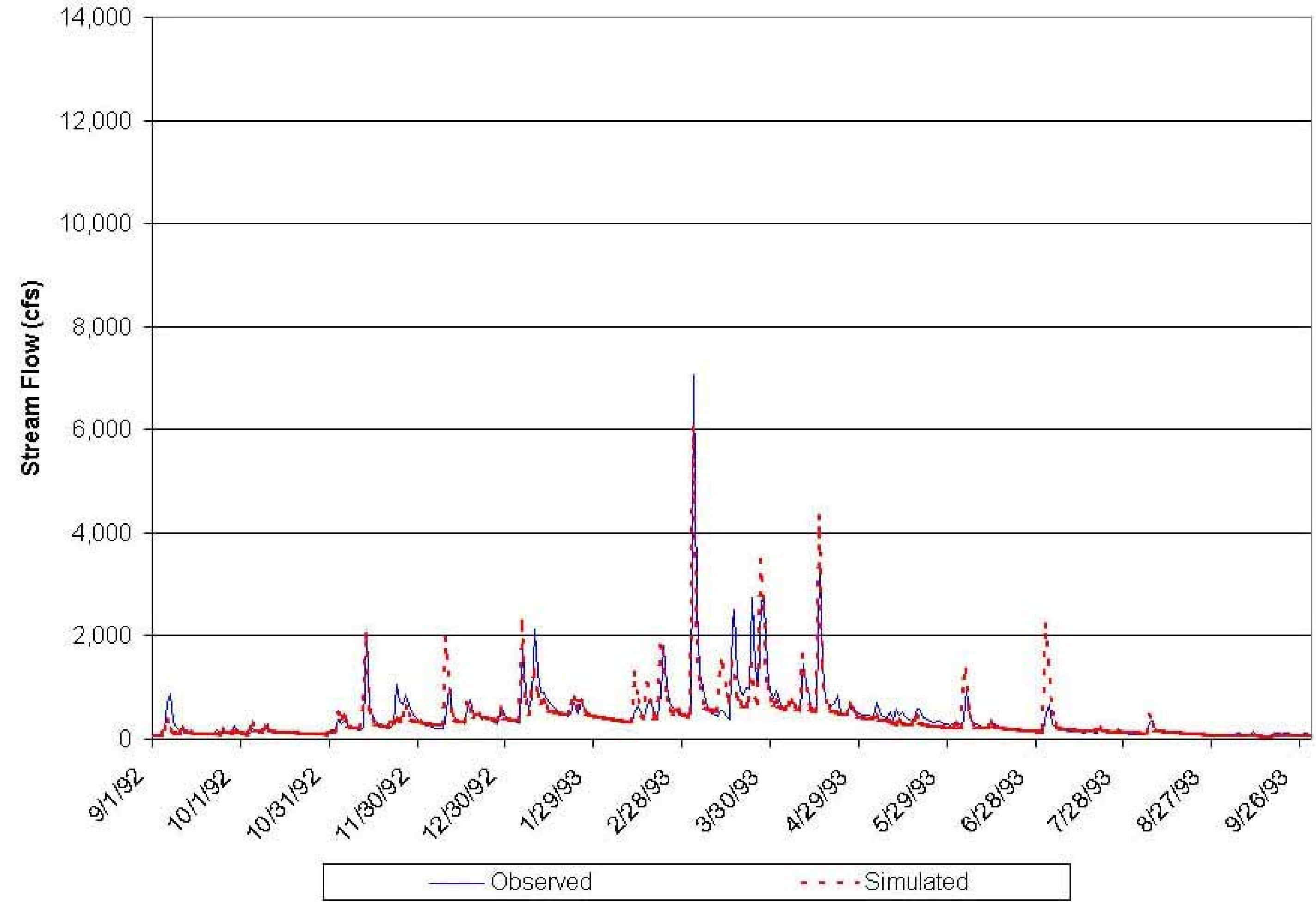

Figure 3.4. Simulated and observed stream flow at Station 02061500 for portion of the calibration period (September 1, 1992 to September 30, 1993)

The portion of water taking different pathways to the stream is important when simulating fecal coliform transport. For the nonpoint sources not directly deposited in the stream, the only pathway to the stream is via surface runoff. Therefore, the portions of water traveling through surface runoff (overland flow), interflow (shallow subsurface flow), and baseflow (ground water flow) were investigated for the simulated data. For the calibration period, the portion of total flow simulated as surface flow, interflow, and direct groundwater discharge were 18%, 16%, and 66%, respectively. There are no observed data or regional values available to check these portions, but they seem reasonable based on the hydrologic assessment of the BOR basin. As a further check of the simulation results, the average annual base flow index was determined for the calibration period by applying the USGS HYSEP Version 2.2 program (Sloto and Crouse, 1996) to the observed data for Station 02061500. The local minima method was used with a 7-day window. The baseflow index is the percent of the total flow that is considered baseflow. The average annual base flow index for the observed data was estimated to be 69.2% for the calibration period, which is slightly greater but sufficiently close to the 66% for the simulated stream flow.

Table 3.4. Big Otter River calibration simulation results for USGS Station 02061500 (January 1, 1990 to May 31, 1995)

Parameter	Simulated (inches)	Observed (inches)	% Percent Error
Total stream flow	91.4	91.6	-0.2%
Summer[a] stream flow	13.0	12.7	2.4%
Winter[b] stream flow	29.7	29.3	1.4%

[a] June – August

[b] December - February

The calibrated data set was then used to predict runoff for a different time period for the observed flow at Station 02061500 to provide a basis for evaluating the appropriateness of the calibrated parameters. A comparison of the simulated and observed stream flow data for Station 02061500 is given in Table 3.5 for the validation period of January 1, 1996 to December 31, 1998.

Table 3.5. Big Otter River validation simulation results for USGS Station 02061500 (January 1, 1996 to December 31, 1998).

Parameter	Simulated (inches)	Observed (inches)	% Percent Error
Total stream flow	55.5	55.6	-0.2%
Summer[a] stream flow	5.8	6.2	-6.5%
Winter[b] stream flow	21.4	21.8	-1.8%

[a] June – August

[b] December - February

There was very good agreement between the observed and simulated stream flow, indicating that the calibrated parameters represent the characteristics of the watershed reasonably well for time periods other than the calibration period. The simulated and observed stream flows for a shorter period within the validation period are shown in Figure 3.5. The simulated data follow the pattern of the observed data well.

To further test if the calibrated input data set represents the hydrologic processes of the constituent watersheds of the BOR basin, an additional validation run was conducted for the estimated stream flow data for Station 02061000 for the period of January 1, 1996 to December 31, 1998. There was good agreement between the simulated and estimated stream flow for Station 02061000 (Table 3.6). Because the data for Station 02061000 was estimated for the simulation period, the criteria for the error rates were relaxed and the comparison of the simulated and estimated flow data served as a qualitative check on the performance of the calibrated input data for smaller subwatersheds of the BOR basin.

Table 3.6. Big Otter River validation simulation results for USGS Station 02061000 (January 1, 1996 to December 31, 1998).

Parameter	Simulated (inches)	Estimated (inches)	% Percent Error
Total stream flow	53.3	57.6	-7.5%
Summer[a] stream flow	5.3	6.4	-17.2%
Winter[b] stream flow	20.6	22.5	-8.4%

[a] June – August

[b] December - February

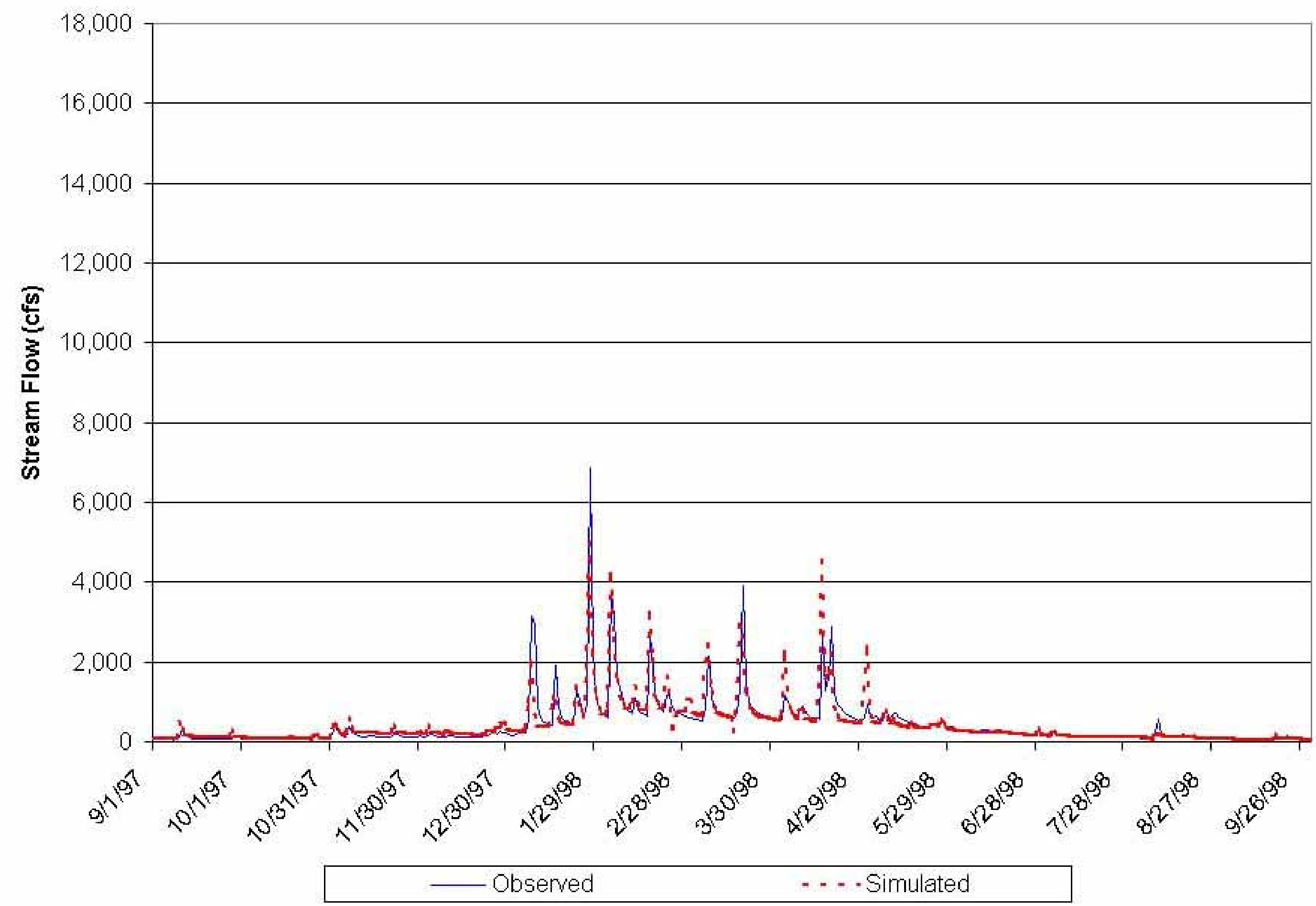

Figure 3.5. Simulated and observed stream flow at station 02061500 for portion of the validation period (September 1, 1997 to September 30, 1998)

In general, the validation results from both USGS stations indicate that the calibrated model characterizes the hydrologic processes of the BOR basin well. Therefore, the calibrated parameters were used in the simulations for the TMDL watersheds, which are subwatersheds of the BOR basin.

3.5.2 Fecal Coliform Calibration and Allocation Simulations

After the hydrologic calibration and validation were completed, the water quality component of HSPF was calibrated for each of the constituent watersheds. The fecal coliform calibrations are discussed in Chapters 4 through 8. The fecal coliform loadings used for the water quality calibration were based on animal numbers that represented the average cattle population from 1993 to 1998. These animal numbers represented the conditions under which the segments in the basin were put on the impaired waters list and under which the majority of the water quality samples were collected. In the past four years, animal operations, particularly dairies, have been closing in many areas of the BOR basin. To represent these reductions in animal populations, additional information was collected on current herd sizes in the BOR basin. These updated numbers were used for the TMDL allocation scenarios. To identify between these two sets of loadings used in different simulations, the fecal coliform loadings derived using the herd sizes from 1993 to 1998 are referred to as the calibration period loadings. The updated herd sizes that include the operation closings since 1996 are referred to as the existing conditions.

3.6 Modeling Allocation Scenarios

The objective of a TMDL is to allocate allowable loads among different pollutant sources so that the appropriate control actions can be taken to achieve water quality standards (USEPA, 1991). The objective of the TMDL development for the impaired segments in the BOR basin was to determine required reductions in fecal coliform loadings from point and nonpoint sources to meet the state water quality standards. The state water quality standard for fecal coliform used in the development of the TMDL allocation was 200 cfu/100mL (30-day geometric mean).

The TMDLs consider all sources contributing fecal coliform. Incorporation of the different sources into the TMDL is defined in the following equation:

$$TMDL = WLA + LA + MOS \qquad [3.2]$$

where,
WLA = wasteload allocation (point source contributions);
LA = load allocation (nonpoint source contributions); and
MOS = margin of safety.

A MOS is included to account for any uncertainty in the TMDL development process. There are several different ways that the MOS could be incorporated into the TMDL (USEPA, 1991). For this study, a MOS of 5% was incorporated explicitly in the TMDL equation, in effect reducing the target fecal coliform concentration (30-day geometric mean) from 200 cfu/100mL to 190 cfu/100mL.

For the phase 1 implementation plan, the state water quality instantaneous standard for fecal coliform of 1000 cfu/100mL was used. The objective of the phase 1 plan was to insure that the 1000 cfu/100mL instantaneous fecal coliform standard was exceeded less than 10 percent of the time. A MOS was not used in the phase 1 implementation plan development.

The period selected for development of the TMDL allocations and implementation plans was January 1, 1993 to December 31, 1998. This period includes both high and low flow years. The simulations were run for a longer time period (January 1, 1989 to December 31, 1998) to minimize risk of errors due to initial conditions at the beginning of the simulation period. The time period selected for TMDL simulations used in the development of the TMDL allocations and the phase 1 implementation plans was January 1, 1989 to December 31, 1998, the period for which most of the observed water quality data were available. This period was selected because it covers the period in which water quality violations were observed and it incorporates a wide range of hydrologic events including both low and high flow conditions.

A variety of allocation scenarios were evaluated to meet the TMDL allocations and phase 1 implementation plan goals. Loadings due to direct pipes were eliminated in all simulations and combined sewer overflows were eliminated in the development of the TMDL allocations. Combined sewer overflows were not eliminated in the phase 1 implementation plans. In general, direct nonpoint source loadings due to cattle and NPS loads due to agricultural activities were reduced first because sensitivity analysis of loadings in each impaired watershed indicated that these loadings were the principal sources of water quality impairment. If the water quality standards could not be met by reducing these allocations, load reductions were obtained from direct nonpoint source loadings from wildlife and NPS loadings from residential and commercial/industrial land uses. Specific details of the allocations and required reductions are presented for each TMDL watershed in Chapters 4 through 8.

4 TMDL FOR SHEEP CREEK WATERSHED

4.1 Watershed Characterization

4.1.1 Water Resources

The Sheep Creek watershed (L23) has 30.3 miles of primary and secondary streams. Starting from the headwaters at the western boundary of the watershed, Sheep Creek flows east and confluences with Stony Creek (Figure 4.1). Stony Creek starts from the northern boundary of the watershed and flows through the Bedford Reservoir and then confluences with Sheep Creek to form the Big Otter River (Figure 4.1). Further downstream, the northwest branch of Big Otter discharges into the Big Otter River. The outlet of the watershed is just upstream of the confluence of the Big Otter River and North Otter Creek (L24). The majority of the watershed is located in the Blue Ridge physiographic province, where geology and relief combine to reduce the potential for groundwater pollution to a low level (VWCB, 1985). The remainder of the watershed is located in the Piedmont physiographic province, with moderate to low groundwater pollution potential (VWCB, 1985). Depth to the seasonal high water table in the watershed is generally greater than 6 ft from the mineral soil surface (SCS, 1989).

4.1.2 Soils

The two major soil associations delineated in the Sheep Creek watershed (L23) are Hayesville-Edneytown-Braddock and Edneytown-Ashe. The remaining eastern portion of the Sheep Creek watershed (L23) is delineated as Cecil-Madison soil association. Detailed descriptions of these soil associations are given in Section 2.5.2.

4.1.3 Land use

The watershed was divided into six subwatersheds to spatially analyze fecal coliform distribution within the watershed (Figure 4.1). Land use distribution in the subwatersheds and the entire Sheep Creek watershed is presented in Table 4.1. The watershed is mainly forested (67.5%), followed by pastures, which account for 24.7% of the acreage.

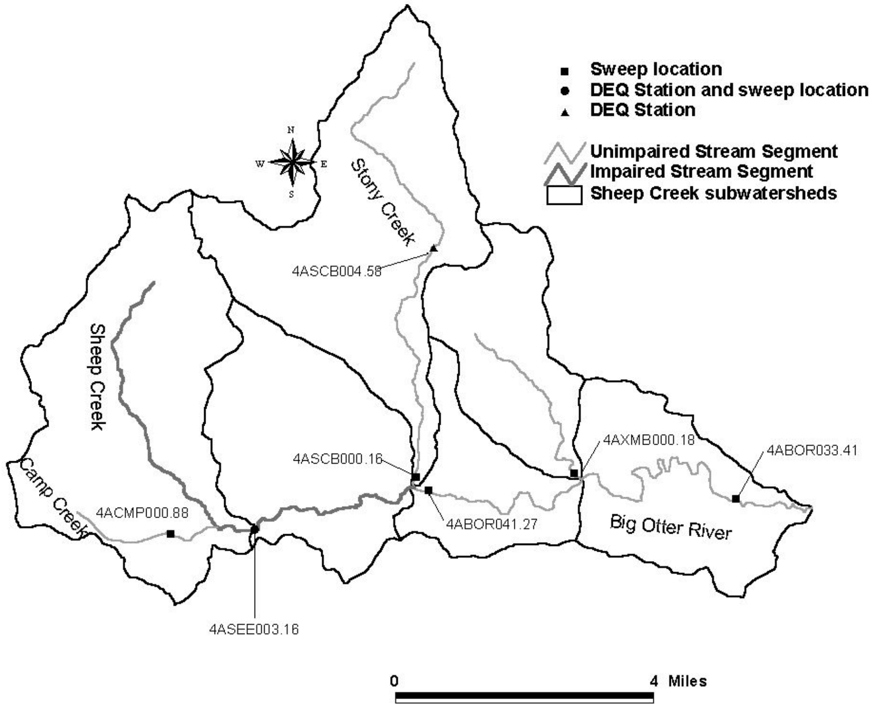

Figure 4.1. Sheep Creek (L23) subwatersheds, stream network, locations of VADEQ water quality monitoring sites and sweep sites for flow and water quality monitoring

Table 4.1. Land use distribution (acres) among the subwatersheds of the Sheep Creek watershed (L23)

Land use	Subwatershed						Total[a]	
	2301	2302	2303	2304	2305	2306	Acres	%
Commercial/ industrial	25	7	6	1	18	13	70	0.2
Cropland	24	526	3	0	72	2	627	1.8
Forest	6,785	2,921	7,596	2,299	1,294	2,561	23,456	67.5
High density residential	86	27	64	68	80	88	413	1.2
Pasture	1,816	2,049	1,028	1,074	1,105	1,503	8,575	24.7
Rural residential	356	164	128	288	225	438	1,599	4.6
Total[a]	**9,092**	**5,694**	**8,825**	**3,730**	**2,794**	**4,605**	**34,740**	**100.0**

[a] Component acreages may not add up due to round-off error.

4.1.4 Flow and Water Quality Data

Historic data

No historic flow data are available for the Sheep Creek watershed. The VADEQ has been collecting monthly water quality samples at two locations (Figure 4.1) since November 1970. However, no water quality samples were collected during July 1979 through July 1993. The water quality samples were analyzed for fecal coliform using the Membrane Filtration Technique (MFT) with a maximum concentration cap of 8,000 cfu/100 mL. Even though most samples were collected at monthly intervals, in some cases, the sampling interval exceeded 3 months.

Monitoring site 4ASCB004.58 (Figure 4.1) is located in the upstream portion of the unimpaired Stony Creek. The second VADEQ site, 4ASEE003.16 (Figure 4.1), is located on the impaired Sheep Creek. Time series data of fecal coliform concentration observed at 4ASEE003.16 are presented in Figure 4.2.

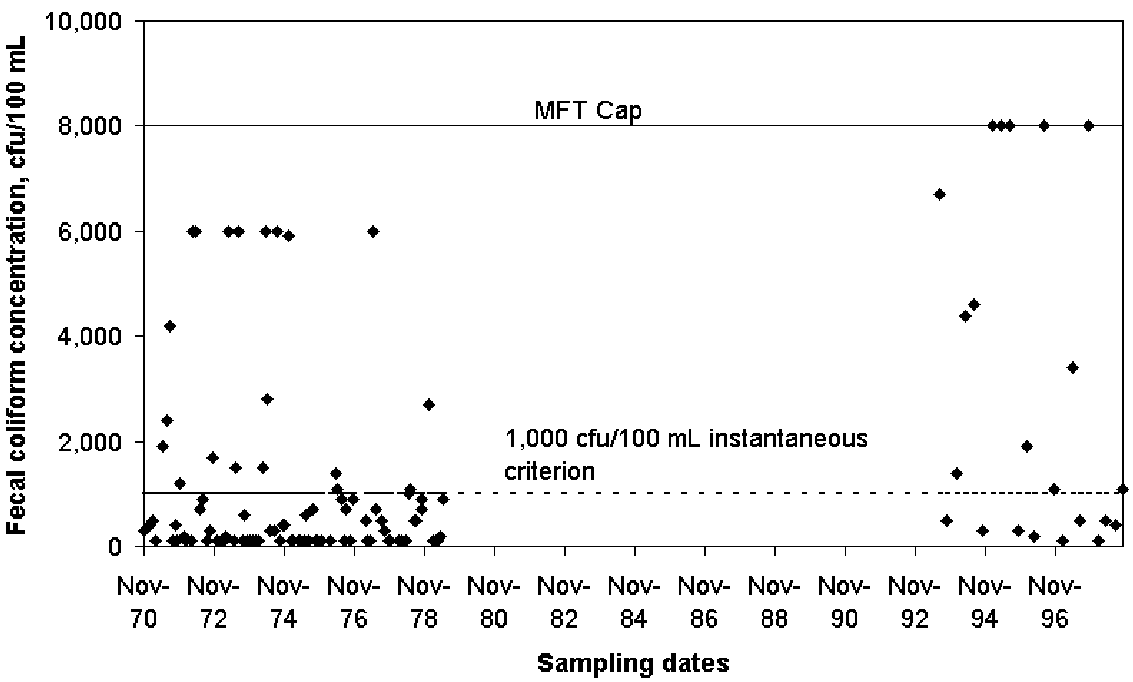

Figure 4.2. Time series of fecal coliform concentration observed at VADEQ monitoring station 4ASEE003.16 on Sheep Creek. No water quality samples were collected during the July 1979 through July 1993 period.

Nearly 60 % of the samples exceeded the instantaneous water quality standard of 1,000 cfu/100 mL. The fecal coliform concentration was at the MFT cap of 8,000 cfu/100 mL in 4.5% of the samples, indicating that the actual concentration could have been higher. Given the irregular sampling interval, it is unclear if a seasonal fecal coliform trend exists. Further, given the lack of flow data, no inferences could be made regarding the impact of flow on fecal coliform concentration.

Water quality sweep and flow measurement

The VADEQ and Virginia Tech conducted a water quality and flow monitoring sweep on March 20-22, 2000. The purpose of the sweep was to assess water quality conditions at various stations within the Sheep Creek watershed. The following factors were considered in selecting the monitoring sites for conducting the sweep:

- Water quality at the monitoring site should be representative of the impact of Land use practices immediately upstream of the site;
- the monitoring site should be in close proximity to a road or bridge so that the site would be located on public land with easy access; and
- the monitoring site should be located at the outlet of the subwatershed.

Six monitoring sites were selected that met the criteria. The sites are described in Table 4.2 and their locations are indicated in Figure 4.1.

Table 4.2. Location and description of sampling sites for instantaneous water quality and flow assessment

ID	Stream	Location
4ACMP000.88	Camp Creek	Bridge on Rt. 684 near intersection of Rt. 684 and Rt. 688, southwest of Penicks Mill
4ASEE003.16	Sheep Creek	Bridge on Rt. 680 near intersection of Rt. 680 and Rt. 684, southeast of Penicks Mill
4ASCB000.16	Stony Creek	Bridge on Rt. 43 near intersection of Rt. 43 and Rt. 682, near Kelso Mill
4ABOR041.27	Big Otter River	Bridge on Rt. 43 near intersection of Rt. 43 and Rt. 682, near Kelso Mill
4AXMB000.18	Big Otter River NW	Bridge on Rt. 640 near intersection of Rt. 640 and Rt. 122, near Big Otter Mill
4ABOR033.41	Big Otter River	Bridge on Rt. 644 near intersection of Rt. 644 and Rt. 673

At each site, staff from VADEQ collected two water samples, one from below the stream surface and another at the bottom of the stream (after disturbing the streambed). Samples were stored on ice and were analyzed for fecal coliform within 24 hours using the Most Probable Number (MPN) method by the Virginia Department of General Services, Division of Consolidated Laboratory Services (DCLS) in Richmond. The MPN method used a maximum detection limit of 160,000 cfu/100 mL. Flow rate was calculated by multiplying the flow velocity (measured with a current meter) with the measured channel cross-sectional area. The results of the sweep are presented in Table 4.3.

Table 4.3. Results of the instantaneous fecal coliform and flow assessment

ID	Stream	Flow (cfs)	Fecal coliform counts (cfu/100 mL)	
			Stream surface[a]	Stream bottom[b]
4ACMP000.88	Camp Creek	4.07	200	680
4ASEE003.16	Sheep Creek	24.74	450	1,500
4ASCB000.16	Stony Creek	32.20	400	180[c]
4ABOR041.27	Big Otter River	74.00	6,400	3,300
4AXMB000.18	Big Otter River NW	9.56	1,100	160,000[d]
4ABOR033.41	Big Otter River	92.20	1,700	160,000[d]

[a] Sample was obtained from just below the stream surface.

[b] Stream bottom was stirred prior to sample collection

[c] Lower limit of detection

[d] Upper limit of detection

In the seven days preceding the sweep, a total of 1.67 inches of precipitation was recorded at Lynchburg Regional Airport with 1.17 inches of the amount recorded in the preceding 48 hours. Fecal coliform concentrations in the stream surface and bottom samples exceeded the instantaneous standard at three and four sites, respectively. Given that the MPN method had an upper detection limit of 160,000 cfu/100 mL, actual fecal coliform concentration could have been higher at the two sites at the 160,000-cap level for stream bottom.

The Land use type upstream of the two locations (4ACMP000.88 and 4ASCB000.16) where fecal coliform concentrations did not exceed the instantaneous standard is mostly forested with some pasture acreage. Higher fecal coliform concentration in the bottom samples close to the watershed outlet could be indicative of fecal coliform accumulation in the stream sediment.

4.2 Source Assessment of Fecal Coliform

Procedures used in quantifying fecal coliform sources are discussed in Section 2.6. Specific information for the Sheep Creek watershed is presented in the following sections.

4.2.1 Point Source

There are no permitted point sources in the Sheep Creek watershed.

4.2.2 Nonpoint Source

Nonpoint sources of fecal coliform in the Sheep Creek watershed include humans, pets, livestock, and wildlife. Fecal coliform directly deposited in the stream by any source is characterized as a direct nonpoint source while fecal coliform applied or deposited on the land is termed as nonpoint source.

Humans

Based on an average household size of 2.5 persons per household, the Sheep Creek watershed has an estimated total human population of 2,283. Distribution of human populations among the subwatersheds is shown in Table 4.4.

Table 4.4. Distribution of human and pet populations in the Sheep Creek watershed (L23)

Subwatershed	Human population	Pet population
2301	535	214
2302	248	99
2303	295	118
2304	310	124
2305	310	124
2306	585	234
Total	**2,283**	**913**

Failing septic systems

Using the procedure outlined in Section 2.6.2.1 of this report and based on an average household size of 2.5 persons and a fecal coliform production of 1.95×10^9 cfu/day, a typical failing septic system contributes 4.88×10^9 cfu/day to the rural residential land use. The numbers of failing septic systems in the subwatersheds of Sheep Creek are shown in Table 4.5.

Biosolids

No biosolids applications were made in the watershed during 1990-1998. As described in Chapter 3, the 1990-1998 period was considered in evaluating fecal coliform loadings under existing conditions.

Table 4.5. Estimated number of unsewered households by age, number of failing septic systems, and straight pipes in the Sheep Creek watershed (L23).

Subwater-shed	Unsewered houses by age (no.)				Failing septic systems (no.)	Straight pipes (no.)
	Pre-1967	1967-1985	Post-1985	Total		
2301	140	1	73	214	58	4
2302	51	0	48	99	22	1
2303	56	0	62	118	24	2
2304	48	0	76	124	21	1
2305	58	0	66	124	25	0
2306	93	13	128	234	44	0
Total	**446**	**14**	**453**	**913**	**194**	**8**

Straight pipes

A household with a straight pipe contributes 4.88×10^9 cfu/day (household size multiplied by daily fecal coliform production) directly into the stream. The numbers of straight pipes were determined in the subwatersheds of Sheep Creek and are given in Table 4.5.

Pets

Based on the assumption of one pet per household, the number of pets in each subwatershed of Sheep Creek was calculated (Table 4.4). There is no fecal coliform loading from pets to the high-density residential land use in this watershed because this land use is comprised of urban and built-up land without any residences. The entire pet loading is applied to the rural residential land use by multiplying the number of pets by the fecal coliform produced by a pet (450×10^6 cfu/day).

Livestock

<u>Beef cattle</u>

Beef cattle in the Sheep Creek watershed (L23) were distributed among the subwatersheds based on their stocking densities and pasture acreages. The number of beef cattle in each subwatershed is shown in Table 4.6.

Table 4.6. Distribution of beef cattle, dairy cattle, and horses among the subwatersheds in the Sheep Creek watershed (L23)

Subwatershed	Beef	Dairy[a]		Horses
		Pre-1996	Current	
2301	318	0	0	86
2302	358	1,076	314	97
2303	180	0	0	49
2304	188	0	0	51
2305	193	0	0	52
2306	263	0	0	71
Total	**1,500**	**1,076**	**314**	**406**

[a] Includes milk cows, dry cows, and heifers

<u>Dairy cattle</u>

Distribution of dairy cattle among the subwatersheds is given in Table 4.6. As discussed in Section 2.6, the pre-1996 dairy numbers are based on the average of the 1987 and 1992 Agricultural Census disaggregated to the hydrologic unit and were used for simulating the calibration period, for which fecal coliform data are available. The current dairy numbers were used for simulating the allocation scenarios.

<u>Horses</u>

Horses were distributed among the subwatersheds based on their stocking densities and pasture acreages. Distribution of horses among the subwatersheds is given in Table 4.6.

Direct manure deposition in streams

The number of beef and dairy cattle in the watershed as well as the percent of pasture acreage with stream access affect manure deposition in the streams. The percentage of pasture with stream access in each subwatershed (Table 4.7) of the Sheep Creek watershed (L23) was calculated using the procedure given in Section 2.6.

Table 4.7. Percentage of pasture with stream access in the subwatersheds of the Sheep Creek watershed (L23)

Subwatershed	Percent of pasture with stream access
2301	78
2302	79
2303	88
2304	68
2305	45
2306	52
Average	**68**

While milk cows are confined part of the year, dry cows, heifers, and beef cattle are not held in confinement. When not confined, milk cows as well as other cattle deposit their waste on pastures and directly into streams. Monthly distribution of cattle in confinement, on pasture, and in streams in the Sheep Creek watershed (Table 4.8) were calculated based on the confinement schedule for milk cows (Table 2.8), time spent by cattle in the streams (Table 2.8), and the percent of pasture with stream access (Table 4.7). Cattle in the streams (Table 4.8) represent the number of cattle defecating in the stream, assuming that 30% of the cattle in and around the stream defecate in the stream.

Fecal coliform deposition in the stream by dairy and beef cattle was calculated by multiplying the number of cattle in the streams by the fecal coliform production of that type of cattle (Table 2.4). Total fecal coliform deposition was calculated by adding the fecal coliform production by the dairy or beef cattle defecating in the streams. Annual fecal coliform loading to the streams in the subwatersheds of Sheep Creek watershed (L23) by dairy and beef cattle are given in Table 4.9.

Table 4.8. Monthly distribution of dairy and beef cattle among confinement, pasture, and stream in the Sheep Creek watershed (L23)

Month	Dairy[a]			Beef		Total	
	Confined[b]	Pasture	Stream	Pasture	Stream	Dairy[a]	Beef
January	295 (65)	778 (248)	3 (1)	1,494	6	1,076 (314)	1,500
February	295 (65)	778 (248)	3 (1)	1,494	6	1,076 (314)	1,500
March	172 (38)	900 (275)	4 (1)	1,494	6	1,076 (314)	1,500
April	147 (33)	923 (279)	6 (2)	1,490	10	1,076 (314)	1,500
May	147 (33)	921 (279)	8 (2)	1,487	13	1,076 (314)	1,500
June	147 (33)	913 (276)	16 (5)	1,474	26	1,076 (314)	1,500
July	147 (33)	913 (276)	16 (5)	1,474	26	1,076 (314)	1,500
August	147 (33)	913 (276)	16 (5)	1,474	26	1,076 (314)	1,500
September	147 (33)	921 (279)	8 (2)	1,487	13	1,076 (314)	1,500
October	147 (33)	923 (279)	6 (2)	1,490	10	1,076 (314)	1,500
November	172 (38)	900 (275)	4 (1)	1,494	6	1,076 (314)	1,500
December	295 (65)	778 (248)	3 (1)	1,494	6	1,076 (314)	1,500

[a] Figures outside the parentheses represent Pre-1996 numbers while the figures inside the parentheses represent current numbers.

[b] Only milk cows are confined.

Table 4.9. Annual fecal coliform loadings to stream and pasture by dairy and beef cattle in the subwatersheds of the Sheep Creek watershed (L23)

Subwatershed	Stream ($\times 10^{12}$ cfu/year)		Pasture ($\times 10^{12}$ cfu/year)	
	Pre-1996	Current	Pre-1996	Current
2301	37.5	37.5	3,810	3,810
2302	101.2	58.9	9,945	5,855
2303	23.9	23.9	2,147	2,147
2304	1.6	1.6	2,256	2,256
2305	13.3	13.3	2,320	2,320
2306	20.7	20.7	3,156	3,156
Total	**198.2**	**155.9**	**23,634**	**19,544**

Direct manure deposition on pastures

When not in confinement, cattle that do not deposit fecal coliform in the streams, contribute to fecal coliform loading on the pastures. Based on the monthly confinement schedule (Table 2.8), stream access by subwatershed (Table 4.7), the number of dairy and beef cattle depositing fecal coliform on pastures are presented in Table 4.8. Total fecal coliform deposition on pastures was calculated by adding the fecal coliform production by the different types of cattle defecating on the pastures. Annual fecal coliform loading on the pastures in the subwatersheds of the Sheep Creek watershed (L23) by dairy and beef cattle are given in Table 4.9.

Land application of dairy manure

A typical milk cow weighs 1,400 lb and produces 17 gallons of liquid manure per day (ASAE, 1998). Hence, annual dairy manure production in confinement during the pre-1996 period was estimated at 1.17 million gallons; current production was estimated to be 0.26 million gallons/year. There are two dairy operations located in subwatershed 2302 of the Sheep Creek watershed (L23) and it was assumed that all dairy manure produced in confinement was applied to cropland and pasture at 8,000 and 4,000 gallons/acre/year, respectively, within this subwatershed. Based on the pre-1996 numbers, it was estimated that 19.4% and 4.3% of cropland and pasture in the Sheep Creek watershed, respectively, received dairy manure according to the application schedule given in Table 2.10. Currently, it is estimated that 4.3% and 0.9% of cropland and pasture, respectively, receive dairy manure. Depending on the storage capacity (and hence, length of storage), fecal coliform in stored manure is subject to die-off (discussion on storage capacity for dairy manure is given in Section 2.6). After accounting for die-off during storage (Section 3.4), fecal coliform loading from dairy manure to cropland in subwatershed 2302 was estimated to be 12.3×10^{12} cfu/year during the pre-1996 period; under current conditions, the cropland receives 2.7×10^{12} cfu/year from dairy manure. Incorporation of applied manure and the impact of incorporation on fecal coliform removal in surface runoff were determined as described in Section 2.6.2.3.

Wildlife

Based on the animal density (animals/acre-habitat) and acreage of habitat (Section 2.6), the wildlife species were distributed among the subwatersheds of the Sheep Creek watershed (Table 4.10). Depending on the wildlife species, an animal deposits part of its waste loading directly into the stream (Table 2.11) while the remainder is deposited on land. The waste that was deposited on land was distributed among the different Land use types that constituted the wildlife species habitat based on their percentages of the total habitat. Annual distribution of fecal coliform loading from wildlife waste to the stream and different Land use types is given in Table 4.11.

Table 4.10. Distribution of wildlife among the different subwatersheds of the Sheep Creek watershed (L23)

Wildlife species	Subwatersheds						Total
	2301	2302	2303	2304	2305	2306	
Deer	428	268	415	175	131	217	1,634
Raccoon	57	33	85	34	34	56	299
Muskrat	255	147	388	158	160	286	1,394
Beaver	27	16	41	17	16	30	147
Goose	36	23	35	15	11	18	138
Duck	16	10	16	7	5	8	62
Mallard	18	11	18	8	6	9	70
Wild Turkey	68	29	76	23	13	26	235

Table 4.11. Annual distribution of fecal coliform from wildlife among the different land use types and streams in the subwatersheds of the Sheep Creek watershed (L23)

Subwater-shed	Annual fecal coliform loading ($\times 10^{12}$ cfu/year)						Total
	Stream	Cropland	Forest	High Density Residential	Pasture	Rural Residential	
2301	12.1	0.2	53.2	0.7	30.3	5.3	**101.8**
2302	7.5	3.8	25.7	0.2	24.8	1.0	**63**
2303	12.8	0.0	73.7	1.4	12.5	2.2	**102.6**
2304	0.0	0.0	21.7	0.4	14.1	1.7	**37.9**
2305	4.4	1.5	15.0	0.5	10.3	1.3	**33**
2306	6.9	0.0	29.4	0.6	13.7	3.0	**53.6**
Total	**43.7**	**5.5**	**218.7**	**3.8**	**105.7**	**14.5**	**391.9**

4.2.3 Summary: Contribution from All Sources

Based on the inventory of sources discussed in Sections 4.2.2.1 through 4.2.2.4, contribution of the different nonpoint sources to direct annual fecal coliform loading to the streams for both the pre-1996 and current conditions is given in Table 4.12. Distribution of annual fecal coliform loading from nonpoint sources among the different Land use categories for both the Pre-1996 and current conditions are also given in Table 4.12.

From Table 4.12, it is clear that nonpoint source loadings to the land surface are nearly 100 times larger than direct nonpoint source loadings to the streams, with pastures accounting for more than 95% of the total fecal coliform load. It could be prematurely assumed that most of the fecal coliform loading in streams originates from upland sources, primarily, from pastures. However, other factors such as precipitation and proximity to streams also impact the amount of fecal coliform from upland areas that reaches the streams.

Table 4.12. Annual fecal coliform loadings to the stream and the various land use categories in the Sheep Creek watershed (L23)

Source	Pre-1996		Current	
	Fecal coliform loading ($\times 10^{12}$ cfu/year)	Percent of total loading	Fecal coliform loading ($\times 10^{12}$ cfu/year)	Percent of total loading
Direct loading to streams				
Cattle in stream	138.7	0.97	96.3	0.95
Wildlife in stream	19.6	0.14	19.6	0.19
Straight pipes	8.9	0.06	8.9	0.09
Loading to land surfaces				
Commercial/industrial	0.12	<0.01	0.12	<0.01
Cropland	12.16	0.08	5.77	0.06
Forest	77.91	0.55	77.91	0.77
High density residential	1.26	<0.01	0.90	<0.01
Pasture	13,807.66	96.8	9715.98	96.0
Rural residential	194.71	1.36	194.71	1.92
Total	**14,261.02**	**100.00**	**10,120.19**	**100**

4.3 Modeling Process

4.3.1 Introduction

The 34,736 acre Sheep Creek watershed is located in the northwest portion of the BOR basin. The upper portions of the watershed are heavily forested and border the Blue Ridge Parkway. Sheep Creek is impaired from its headwaters starting just west of the junction of State Highway 614 and the Blue Ridge Parkway to its confluence with the Big Otter River near Penicks Mill, Virginia. The VADEQ monitoring station is located at the halfway point along Sheep Creek. Since no monitored flow data were available at this station or at any other point within the Sheep Creek watershed, the hydrology parameter set developed during the BOR hydrology calibration was used for Sheep Creek. The water quality parameters were calibrated to the observed data at the Sheep Creek VADEQ monitoring station.

4.3.2 Selection of Subwatersheds

The Sheep Cheek watershed was subdivided into six subwatersheds and seven stream reaches (Fig. 4.1) for modeling purposes. The subwatersheds and reaches were delineated based on the stream network, Land use patterns and the presence of monitoring stations and point source discharges. Four direct NPS discharges due to direct pipes from on-site wastewater disposal systems were assumed and simulated.

4.3.3 Input Data

The HSPF model requires a wide variety of input data to describe hydrology, water quality, and Land use characteristics of the watershed. The different types and sources of input data used to develop the TMDL for the Sheep Creek watershed are discussed below.

Climatologic Data

Hourly precipitation data were obtained from the National Climatic Data Center's (NCDC) cooperative weather station at Lynchburg Municipal Airport, located approximately 10 miles east of the watershed. A complete set of surface meteorological data and hourly precipitation data was available for the Lynchburg station. Detailed descriptions of the weather data and the procedure for converting the raw data into the required data set are presented in Appendix B.

Hydrology Model Parameters

The hydrology parameters required by PWATER and IWATER were defined for every land use category for each subwatershed. For each reach, a function table (FTABLE) is required to describe the relationship between water depth, surface area, volume, and discharge (Donigian et al., 1995). These parameters were estimated by surveying representative channel cross-sections in each subwatershed. Hydrology parameters required for the PWATER, IWATER, HYDR, and ADCALC sub-modules are listed in

Appendix B.1 of BASINS version 2.0 User's Manual (Lahlou et al., 1998). Parameters required as inputs for PQUAL, IQUAL, and GQUAL are given Appendix B.1 of BASINS version 2.0 User's Manual (Lahlou et al., 1998). Values for the parameters were estimated based on local conditions when possible, otherwise the default parameters provided within HSPF were used. Key HSPF parameters used in the Sheep Creek simulations are listed in Table 4.13.

Land use

VADCR identified 24 land uses in the BOR basin. As described in Chapter 3, the 24 land uses were consolidated into six categories based on hydrologic and waste application/production characteristics (Table 2.2). The land use categories were assigned pervious/impervious percentages, which allowed a land use with both pervious and impervious fractions to be modeled using both the PERLND and IMPLND modules. Land use data were used to select several hydrology and water quality parameters for the simulations.

4.3.4 Model Calibration and Validation

The water quality component of HSPF was calibrated by comparing the simulated daily fecal coliform values with 24 fecal coliform samples collected by VADEQ between August 1993 and October 1999. The goodness of the calibration was evaluated visually using graphs of simulated and observed values. The primary water quality parameter adjusted during calibration was the pervious land wash-off factor (WSQOP), which was changed from the initial value of 1.8 to 1.0 to increase fecal coliform concentrations during runoff events. This parameter was adjusted until there was good agreement between simulated and observed concentrations. Other HSPF fecal coliform parameters used in model calibration are presented in Table 4.13. As shown in Figure 4.3, the calibrated HSPF water quality parameters fit the observed data for the existing conditions well and the model was judged to be adequately calibrated.

Table 4.13. Input parameters used in HSPF simulations for Sheep Creek.

			RANGE OF VALVES						
PARAMETER	**DEFINITION**	**UNITS**	**TYPICAL**		**POSSIBLE**		**START**	**FINAL**	**FUNCTION OF…**
PERLIND			**MIN**	**MAX**	**MIN**	**MAX**		**CALIB.**	
PWAT-PARM2									
FOREST	Fraction forest cover	none	0.00	0.5	0	0.95	0.0, 1.0	1.0 forest, 0.0 other	Forest cover
LZSN	Lower zone nominal soil moisture storage	inches	3	8	2	15	14.1	4.5-11.3[1]	Soil properties*
INFILT	Index to infiltration capacity	in/hr	0.01	0.25	0.001	0.5	0.16	0.054-0.086[1]	Soil and cover conditions
LSUR	Length of overland flow	feet	200	500	100	700	300	300	Topography
SLSUR	Slope of overland flowplane	none	0.01	0.15	0.001	0.3	0.035	0.05	Topography
KVARY	Groundwater recession variable	1/in	0	3	0	5	0	0	Calibrate*
AGWRC	Base groundwater recession	none	0.92	0.99	0.85	0.999	0.98	0.97	Calibrate*
PWAT-PARM3									
PETMAX	Temp below which ET is reduced	deg. F	35	45	32	48	40	40	Climate, vegetation
PETMIN	Temp below which ET is set to zero	deg. F	30	35	30	40	35	35	Climate, vegetation
INFEXP	Exponent in infiltration equation	none	2	2	1	3	2	2	Soil properties
INFILD	Ratio of max/mean infiltration capacities	none	2	2	1	3	2	2	Soil properties
DEEPFR	Fraction of GW inflow to deep recharge	none	0	0.2	0	0.5	0.1	0	Geology*
BASETP	Fraction of remaining ET from baseflow	none	0	0.05	0	0.2	0.02	0.0-0.02[1]	Riparian vegetation*
AGWETP	Fraction of remaining ET from active GW	none	0	0.05	0	0.2	0	0	Marsh/wetlands ET*
PWAT-PARM4									
CEPSC	Interception storage capacity	inches	0.03	0.2	0.01	0.4	0.1	monthly[1]	Vegetation
UZSN	Upper zone nominal soil moisture storage	inches	0.10	1	0.05	2	1.128	0.235-2.05[1]	Soil properties
NSUR	Mannings' n (roughness)	none	0.15	0.35	0.1	0.5	0.2	0.06-0.09[1]	Land use, surface condition
INTFW	Interflow/surface runoff partition parameter	none	1	3	1	10	0.75	1.4	Soils, topography, land use
IRC	Interflow recession parameter	none	0.5	0.7	0.3	0.85	0.5	0.3	Soils, topography, land use
LZETP	Lower zone ET parameter	none	0.2	0.7	0.1	0.9	monthly	monthly[1]	Vegetation
QUAL-INPUT									
ACQOP	Rate of accumulation of constituent	#/day						monthly[1]	Land use
SQOLIM	Maximum accumulation of constituent	#						9 x ACQOP	Land use
WSQOP	Wash-off rate	in/hr						1	Land use
IOQC	Constituent conc. in interflow	$\#/ft^3$						2832	Land use

[1] Varies with land use

Table 4.13. Input parameters used in HSPF simulations for Sheep Creek (Continued).

			RANGE OF VALVES						
PARAMETER	**DEFINITION**	**UNITS**	**TYPICAL**		**POSSIBLE**		**START**	**FINAL**	**FUNCTION OF…**
PERLIND			**MIN**	**MAX**	**MIN**	**MAX**		**CALIB.**	
AOQC	Constituent conc. in active groundwater	$\#/ft^3$						1416	Land use
IMPLND									
IWAT-PARM2									
LSUR	Length of overland flow	feet	200	500	100	700	300	300	Topography
SLSUR	Slope of overland flowplane	none	0.01	0.15	0.001	0.3	0.035	0.01	Topography
NSUR	Mannings' n (roughness)	none	0.15	0.35	0.1	0.5	0.2	0.05	Land use, surface condition
RETSC	Retention/interception storage capacity	inches	0.03	0.2	0.01	0.4	0.1	0.065	Land use, surface condition
IWAT-PARM3									
PETMAX	Temp below which ET is reduced	deg. F	35	45	32	48	40	40	Climate, vegetation
PETMIN	Temp below which ET is set to zero	deg. F	30	35	30	40	35	35	Climate, vegetation
IQUAL									
ACQOP	Rate of accumulation of constituent	#/day						1.00E+07	Land use
SQOLIM	Maximum accumulation of constituent	#						3.00E+07	Land use
WSQOP	Wash-off rate	in/hr						1.8	Land use
RCHRES									
HYDR-PARM2									
KS	Weighting factor for hydraulic routing							0.5	
GQUAL									
FSTDEC	First order decay rate of the constituent	1/day						1.15	
THFST	Temperature correction coeff. for FSTDEC							1.05	

[1] Varies with land use

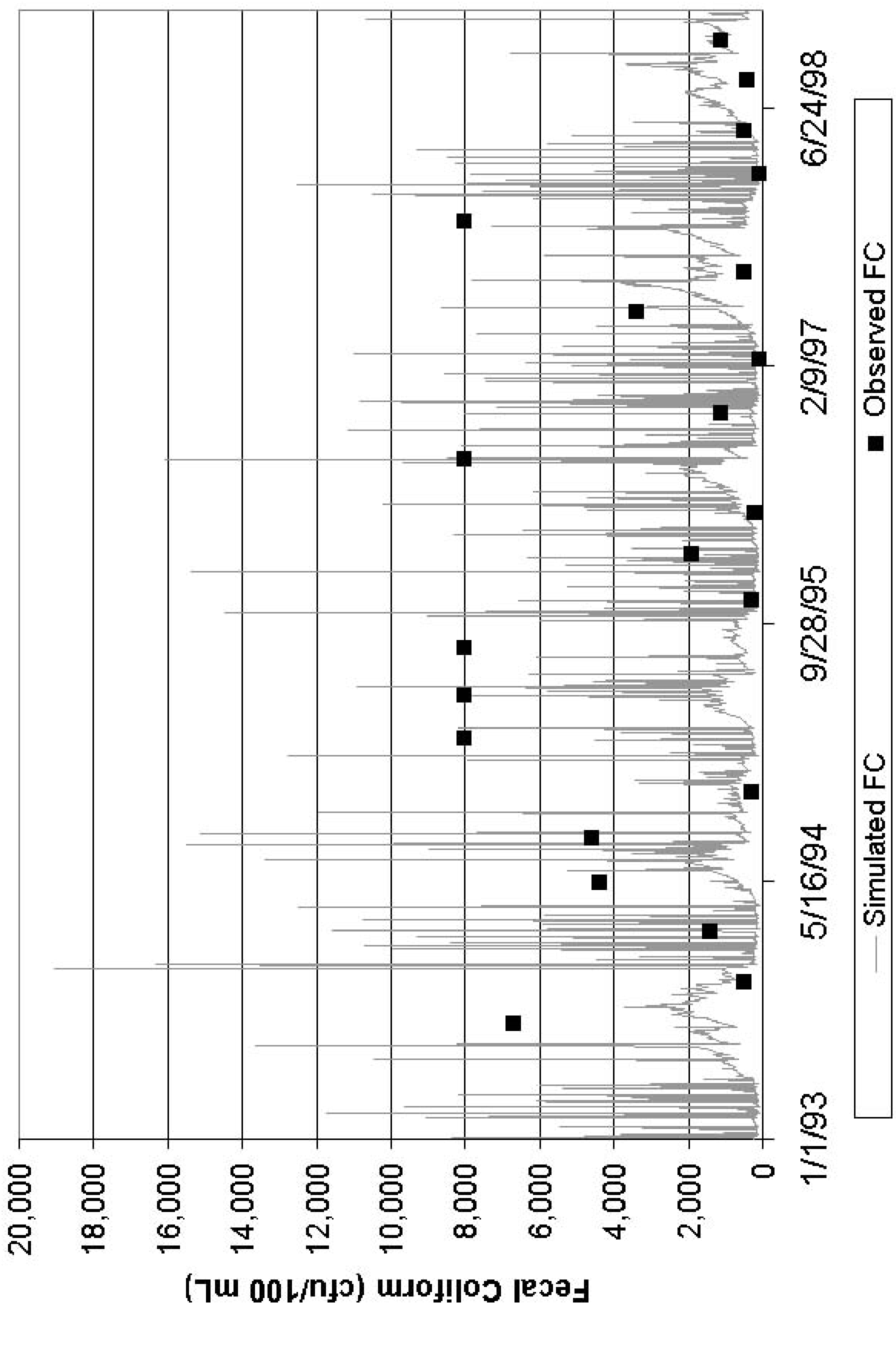

Figure 4.3. Simulated and observed fecal coliform concentrations for Sheep Creek.

Figure 4.3.

4.4 Load Allocations

4.4.1 Background

The objective of a TMDL is to allocate allowable loads among different pollutant sources so that the appropriate control actions can be taken to achieve water quality standards (USEPA, 1991). The objective of the TMDL for Sheep Creek was to determine what reductions in fecal coliform loadings from point and nonpoint sources are required to meet state water quality standards. Sheep Creek watershed is part of the headwaters of the BOR basin. In developing the TMDL, water quality was simulated at three points within the Sheep Creek HU and the final TMDL was developed for the impaired stream reach that was the most restrictive (required the greatest reductions in loadings to meet the water quality standard). The most restrictive stream reach was located on Sheep Creek between the confluence of Sheep and Camp Creeks and the confluence of Sheep and Stony Creeks (end of the impaired segment). Load reductions were applied uniformly across the entire Sheep Creek watershed even though only two subwatersheds (2301, 2302) contribute loadings to the impaired segment (Figure 4.4). Reductions in loadings in subwatersheds downstream of the Sheep Creek impaired segment were required for successful implementation of the Lower Big Otter River watershed TMDL.

The state water quality standard for fecal coliform used in the development of the TMDL was the 30-day geometric mean standard of 200 cfu/100mL. The TMDL considers all sources contributing fecal coliform to Sheep Creek. The sources can be separated into nonpoint and point (or direct) sources. The incorporation of the different sources into the TMDL are defined in the following equation:

$$TMDL = WLA + LA + MOS \qquad [4.1]$$

where,

WLA = waste load allocation (point source contributions);
LA = load allocation (nonpoint source contributions); and
MOS = Margin of safety.

A MOS is included to account for uncertainty in the TMDL development process. There are several ways that the MOS can be incorporated into the TMDL (USEPA, 1991). For the Sheep Creek TMDL, a margin of safety of 5% (i.e. MOS = 10 cfu/100mL) was used. By subtracting the MOS from the TMDL standard of 200 cfu/100mL, the goal of the TMDL allocation was that the combined point source (WLA) and nonpoint source (LA) loads be below the target fecal coliform concentration (30-day geometric mean) of 190 cfu/100mL.

The time period selected for the calibration and load allocation was January 1, 1993 to December 31, 1998. This period incorporates a wide range of hydrologic events including both low and high flow conditions. This is also a period in which observed data were available.

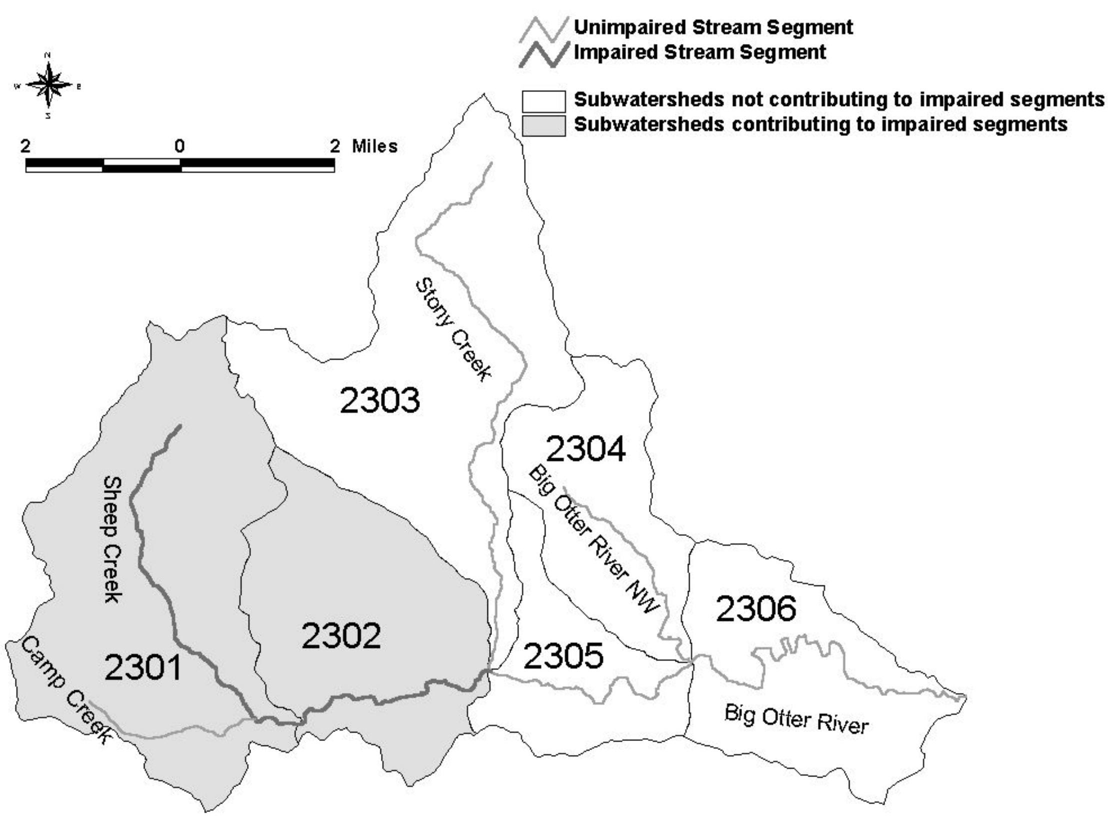

Figure 4.4. Sheep Creek watershed with the subwatersheds contributing to the impaired segment shaded.

4.4.2 Calibration Period and Existing Conditions

The simulation of calibration period conditions provides the baseline for evaluating reductions required for the TMDL allocation. Cattle populations were reduced for the existing condition simulations, compared to the calibration period. The cattle population during the calibration period represented the average cattle populations in the watersheds from 1993 to 1998. The existing condition cattle populations account for the known decreases in dairy cattle populations during the last three to four years. Fecal coliform loads (NPS and direct NPS) used in the development of the TMDL allocation represent the cattle populations for "existing conditions". Analysis of the simulation results for the calibration period (Table 4.14) shows that fecal coliform loading from direct deposition by cattle is responsible for an average of about 40% of the mean daily fecal coliform concentration in Sheep Creek. Loads from PLS on average contribute about 38% of the mean daily fecal coliform concentration, while direct deposition from wildlife accounts for about 13%. About 8% of the mean daily fecal coliform concentration is from straight pipes. The other sources, interflow and groundwater, together contribute less than 1% of the mean daily concentration.

Table 4.14. Relative contributions of different fecal coliform sources to the overall mean fecal coliform concentration for the calibration period.

Fecal Coliform Source	Mean Daily Fecal coliform Concentration Attributable to Source, cfu/100mL	Relative Contribution by Source %
Baseline -- All Sources	1,160.0	100.0%
Direct Deposit from Cattle only	467.0	40.3%
Direct Deposit from Wildlife only	153.0	13.2%
Straight Pipe Discharge only	90.0	7.8%
Loads from PLS only	445.0	38.4%
Loads from ILS only	0.0	0.0%
Contribution from Interflow and groundwater	5.0	0.4%

In Table 4.15, the concentrations of fecal coliform from direct nonpoint sources for the existing conditions are listed. Simulated 30-day mean fecal coliform concentrations at the end of impairment due to existing Sheep Creek loads are shown in Figure 4.5 along with the geometric mean goal. Simulated concentrations are generally above the geometric mean standard during the summer months since less dilution occurs during these months.

Table 4.15. Fecal coliform loadings for Sheep Creek* from direct nonpoint sources

Source	Fecal coliform loading ($\times 10^{12}$ cfu/year)	Percent of total loading
Cattle in stream	96.3	77.16
Wildlife in stream	19.6	15.71
Straight pipes	8.9	7.13
Total	**124.8**	**100.00**

*at the end of impairment.

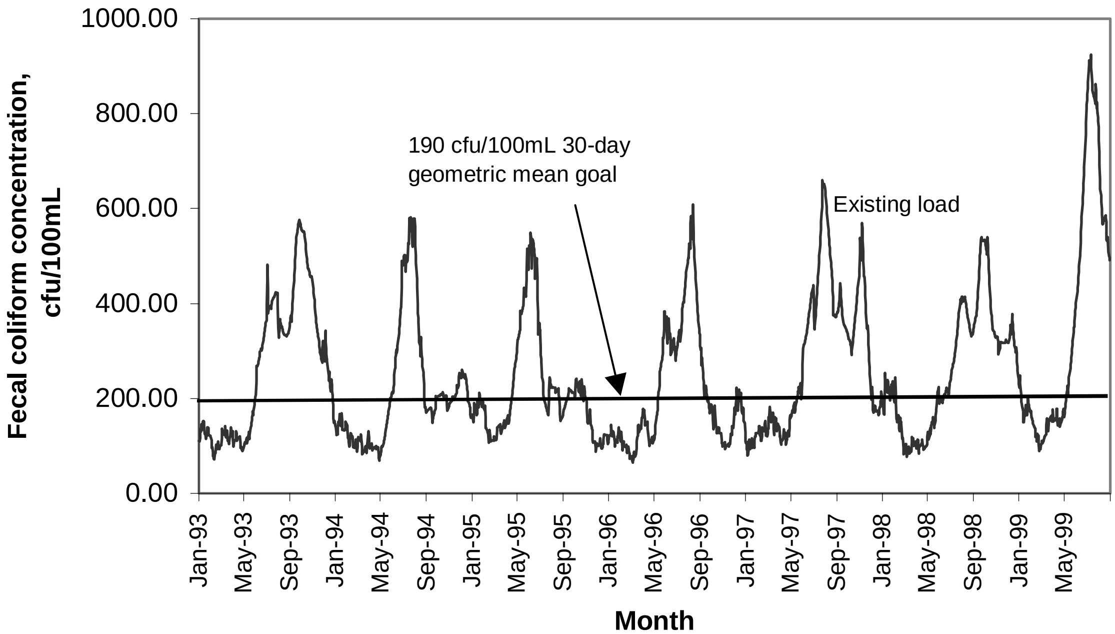

Figure 4.5. Simulated 30-day mean fecal coliform concentrations in Sheep Creek (at the lower end of impairment) due to existing loads.

Direct deposits by cattle are a critical source, especially during the summer, when increased time spent in streams corresponds with the decreased dilution associated with low stream flow. In summer months, it is estimated that cattle with access to streams spend two hours per day in water (Table 2.8). Hence, of the 1,229 cattle on pastures with stream access, an equivalent of 102 cattle spend the entire day in the stream. With the estimate that 30% of the feces of these cattle is deposited directly to the streams, the waste equivalent of 31 cattle is deposited directly in the streams. This represents approximately 2.5% of the manure load of cattle on pastures with stream access. The fraction of manure directly deposited in the stream at other times of the year is lower, but can still contribute to water quality standard exceedances during low-flow periods.

4.4.3 Allocation Scenarios

Several allocation scenarios were evaluated to meet the 30-day geometric mean TMDL goal of 190 cfu/100mL. Scenarios 6 and 7 meet the TMDL allocation requirement of no violations of the 190 cfu/100mL 30-day geometric mean goal (Table 4.16). However, scenario 7 was selected for the TMDL allocation since an additional 5% reduction in direct deposition by wildlife allows a 15% less reduction in NPS loadings than scenario 6 from pervious agricultural land segments. Loadings from straight pipes were reduced by 100% for all scenarios. Reductions in direct deposition from cattle to streams had the greatest impact on concentrations of fecal coliform in the impaired stream segment. When the reduction in direct deposition by cattle was changed from 90% (scenario 2) to 98% (scenario 3), the percent exceedances of the 190 cfu/100mL goal was reduced from 38.7% to 5.2%. Since complete elimination of direct deposition from cattle (scenarios 4 and 5) did not achieve the TMDL goal, increased reductions had to be made for direct deposition by wildlife and NPS loads from pervious agricultural land segments. Ultimately, the TMDL allocation plan for Sheep Creek required reductions in direct deposition from cattle and wildlife of 100 and 80%, respectively; a 60% reduction in NPS loads from pervious agricultural land segments; and elimination of all direct pipe discharges.

Table 4.7 shows the loads from nonpoint sources for all Land uses and the results of the 60% reduction called for by the TMDL allocation scenario (scenario 7 in Table 4.16). The reductions in direct nonpoint loads required by allocation scenario 7 are shown in Table 4.18. The graph of 30-day geometric mean fecal coliform concentrations for existing conditions and for the selected TMDL allocation scenario (Figure 4.6) shows that simulated concentrations do not exceed the geometric mean goal of 190 cfu/100mL for the entire allocation study period under the TMDL reductions.

Table 4.16. Fecal coliform TMDL allocation scenarios for the Sheep Creek

Scenario Number	Scenario Code	Percent reduction in loading from existing condition[1]				Percentage of days with 30-day GM > 190 cfu/100mL
		Direct wildlife deposits	Direct cattle deposits	NPS from Ag land segments	Direct pipes	
1	ShA36l2	50	90	25	100	58
2	ShA36j2	75	90	60	100	38.7
3	ShA36h2	75	98	60	100	5.2
4	ShA36b2	75	100	0	100	1.3
5	ShA36c2	75	100	50	100	1.4
6	ShA36d2	75	100	75	100	0
7	**ShA36g2**	**80**	**100**	**60**	**100**	**0**

Bold indicates the scenario selected

Table 4.17. Annual NPS loads to Sheep Creek* for existing conditions and corresponding reductions for TMDL allocation plan (scenario 7).

Pervious Land Segment	Existing Conditions		TMDL Allocation Plan (scenario 7)	
	Existing load ($\times 10^{12}$ cfu)	Percent of total load to stream from NPS	TMDL NPS allocation load ($\times 10^{12}$ cfu)	Percent reduction from existing load
Commercial/Industrial	<0.01	< 0.1	<0.01	0
Cropland	1.07	< 0.1	0.43	60
Forest	35.68	0.9	35.68	0
High Density Residential	0.03	< 0.1	0.03	0
Pasture	4,112.79	98.9	1,645.12	60
Rural Residential	9.99	0.2	9.99	0
Total	**4,159.56**	**100.0**	**1,691.25**	**59.3**

[a] Only impaired subwatersheds

Table 4.18. Annual direct NPS loads to Sheep Creek for existing conditions and corresponding reductions for TMDL allocation plan (scenario 7).

Source	Existing Conditions		Allocation Scenario	
	Fecal Coliform Load* ($\times 10^{12}$ cfu/year)	Percent of total load to stream from direct nonpoint sources	NPS allocation load* ($\times 10^{12}$ cfu/year)	Percent reduction
Cattle in stream	96.3	77.2	0.0	100.0
Wildlife in stream	19.6	15.7	3.9	80.0
Straight pipes	8.9	7.1	0.0	100.0
Total	**124.8**	**100.0**	**3.9**	**96.9**

* contributions only from subwatersheds contributing to the impaired segment

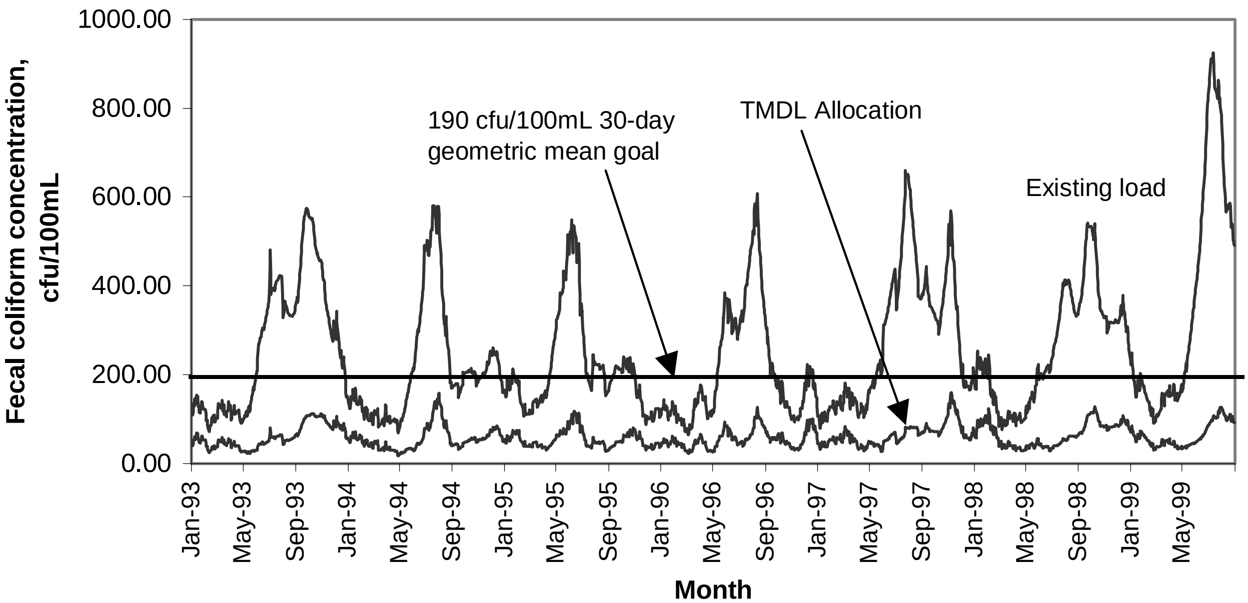

Figure 4.6. TMDL allocation plan (Scenario 7), the 190 cfu/100mL 30-day geometric mean goal, and existing conditions for Sheep Creek.

4.4.4 Summary of TMDL Allocation

A TMDL for fecal coliform has been developed for Sheep Creek. The TMDL addresses the following issues.

1. The TMDL meets the water quality standard of no exceedances of the 30-day geometric mean fecal coliform concentration of 200 cfu/100 mL.

2. A MOS of 5% was incorporated in the development of the TMDL plan.

3. The TMDL accounts for fecal coliform from human, domestic/agricultural animals, and wildlife sources.

4. Both high- and low-flow stream conditions were considered in developing the TMDL. In the Sheep Creek watershed, low flow conditions were found to be the environmental condition most likely to cause a violation of the 30-day geometric mean.

5. Both the flow regime and fecal coliform loadings are seasonal, with higher loadings and in-stream concentrations during the summer than in the winter. The TMDL accounts for these seasonal effects.

6. A TMDL allocation scenario to meet the 30-day geometric mean water quality goal of 190 cfu/100mL requires: a 100% reduction in direct deposits of cattle manure to streams, an 80% reduction in direct deposits by wildlife to streams, a 60% reduction in NPS loadings from agricultural land segments (cropland and pasture), and elimination of direct pipe discharges. The annual fecal coliform loads for the selected TMDL allocation scenario are summarized in Table 4.19.

Table 4.19. Annual fecal coliform loadings (cfu/year) for the Sheep Creek watershed (L23) fecal coliform TMDL.

Subwatershed	Point Source Loads	Nonpoint Source Loads	Margin of Safety[a]	TMDL Annual Load
Sheep Creek	$<0.1 \times 10^{12}$	$1,695.2 \times 10^{12}$	89.2×10^{12}	$1,784.4 \times 10^{12}$

[a] Five percent of TMDL

5 TMDL FOR ELK CREEK WATERSHED

5.1 Watershed Characterization

5.1.1 Water Resources

The Elk Creek watershed (L25) has 39.6 miles of primary and secondary streams. The stream network in the Elk Creek watershed is comprised of Roaring Run, Elk Creek, and the BOR (Figure 5.1). Close to the headwaters of the watershed at the western boundary, Roaring Run confluences with the BOR. Starting from the northern boundary of the watershed, Elk Creek flows along the north-south axis of the watershed to confluence with the BOR (Figure 5.1). The watershed is located in the Piedmont physiographic province with moderate to low groundwater pollution potential (VWCB, 1985). Depth to the seasonal high water table in the watershed is generally greater than 6 ft from the mineral soil surface (SCS, 1989).

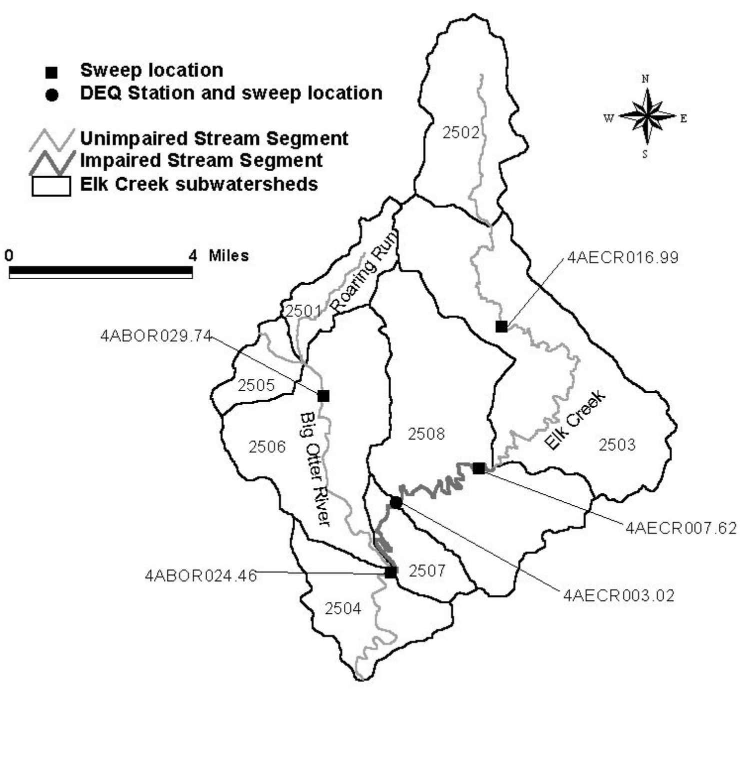

Figure 5.1. Elk Creek (L25) subwatersheds, stream network, locations of VADEQ water quality monitoring sites and sweep sites for flow and water quality monitoring

5.1.2 Soils

The two soil associations found in the Elk Creek watershed (L25) are Edneytown-Ashe and Cecil-Madison. The Edneytown-Ashe soils are found mainly in the headwaters while Cecil-Madison soils are the dominant soil association in the remaining area of the watershed. Detailed descriptions of these soil associations are given in Section 2.5.2.

5.1.3 Land use

The watershed was divided into eight subwatersheds to spatially analyze fecal coliform distribution within the watershed (Figure 5.1). Land use distribution in the subwatersheds and the entire Elk Creek watershed (L25) is presented in Table 5.1. About half of the watershed is forested (49.4%), while pastures account for 33.4% of the acreage.

Table 5.1. Land use distribution (acres) among the subwatersheds of the Elk Creek watershed (L25)

Land use	Subwatershed								Total[a]	
	2501	2502	2503	2504	2505	2506	2507	2508	Acres	%
Commercial/ industrial	1	0	104	47	7	70	17	57	303	0.7
Cropland	0	0	211	25	0	94	11	274	615	1.4
Forest	1,344	4,007	4,356	1,876	955	3,534	1,016	4,108	21,196	49.4
High density residential	6	1	613	74	37	101	52	127	1,011	2.4
Pasture	712	668	3,751	1,327	266	2,666	378	4,573	14,341	33.4
Rural residential	131	8	2,087	205	180	969	351	1,484	5,415	12.6
Total[a]	**2,194**	**4,684**	**11,122**	**3,554**	**1,445**	**7,434**	**1,825**	**10,623**	**42,880**	**100.0**

[a] Component acreages may not add up due to round-off error.

5.1.4 Flow and Water Quality Data

Historic data

The VADEQ collected monthly water quality samples at monitoring site 4AECR003.02 (Figure 5.1) from August 1992 until December 1998. No concomitant flow data were collected at the monitoring site. The water quality samples were analyzed for fecal coliform using the MFT with a maximum concentration cap of 8,000 cfu/100 mL. Even though most samples were collected at monthly intervals, in some cases, the sampling interval exceeded three months. Monitoring site 4AECR003.02 is located approximately midway on the impaired segment of Elk Creek before it confluences with the BOR. Time series data of fecal coliform concentration observed at 4AECR003.02 are presented in Figure 5.2.

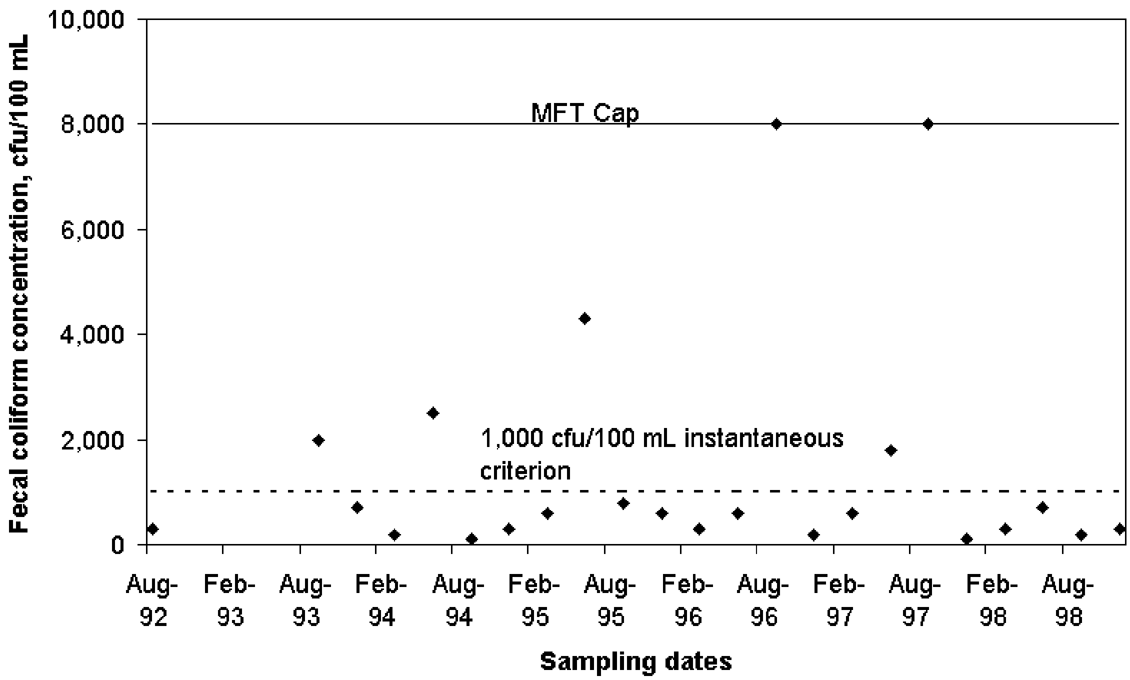

Figure 5.2. Time series of fecal coliform concentration observed in VADEQ monitoring station 4AECR003.02 on Elk Creek

Twenty-six percent of the samples exceeded the instantaneous standard of 1,000 cfu/100 mL. Two of 23 samples had fecal coliform concentration of 8,000 cfu/100 mL (MFT cap), indicating that the actual concentrations could have been higher. Given the irregular sampling interval, it was unclear if a seasonal fecal coliform trend existed. Further, given the lack of flow data, no inferences could be made regarding the impact of flow on fecal coliform concentration.

Water quality sweep and flow measurement

The VADEQ and Virginia Tech conducted a water quality and flow-monitoring sweep on March 20-22, 2000. The purpose of the sweep was to assess water quality conditions at various stations within the Elk Creek watershed. The following factors were considered in selecting the monitoring sites for conducting the sweep.

- Water quality at the monitoring site should be representative of the impact of Land use practices immediately upstream of the site;
- the monitoring site should be in close proximity to a road or bridge so that the site would be located on public land with easy access; and
- the monitoring site should be located at the outlet of the subwatershed.

Five monitoring sites were selected that met the criteria. The sites are described in Table 5.2 and their locations are indicated in Figure 5.1.

Table 5.2. Location and description of sampling sites for instantaneous water quality and flow assessment

ID	Stream	Location
4ABOR024.46	Big Otter River	Bridge on US Rt. 460 near intersection of US Rt. 460 and Rt. 706; near confluence of Elk Creek and Big Otter River
4AECR003.02	Elk Creek	Bridge on Rt. 668 southeast of intersection of Rt. 668 and Rt. 706
4AECR007.62	Elk Creek	Bridge on Rt. 643 north of intersection of Rt. 643 and Rt. 705
4AECR016.99	Elk Creek	Bridge on Rt. 664 west of Lynchburg, between junctions with Rt. 646 (668) and Rt. 663
4ABOR029.74	Big Otter River	Bridge on US Rt. 221 near intersection of US Rt. 221 with Rt. 670

At each site, staff from VADEQ collected two water samples, one from below the stream surface and another at the bottom of the stream (after disturbing the streambed). Samples were stored on ice and were analyzed for fecal coliform within 24 hours using the MPN method by the DCLS in Richmond. The MPN method used a maximum detection limit of 160,000 cfu/100 mL. Flow rate was calculated by multiplying the flow velocity (measured with a current meter) with the measured channel cross-sectional area. The results of the sweep are presented in Table 5.3.

In the seven days preceding the sweep, a total of 1.67 inches of precipitation was recorded at Lynchburg Regional Airport with 1.17 inches of rainfall recorded in the preceding 48 hours. Fecal coliform concentrations in the stream surface and bottom samples exceeded the instantaneous standard at all sites. Fecal coliform concentrations in both the stream surface and bottom samples were higher at 4ABOR024.46 which is downstream from the confluence of Elk Creek and the BOR compared with 4ABOR029.74 which is upstream from the confluence of Elk Creek and the BOR (Figure 5.1). High fecal coliform concentration in the bottom samples could be indicative of fecal coliform accumulation in the stream sediment.

Table 5.3. Results of the instantaneous fecal coliform and flow assessment

ID	Stream	Flow (cfs)	Fecal coliform counts (cfu/100 mL)	
			Stream surface[a]	Stream bottom[b]
4ABOR024.46	Big Otter River	297.0	7,000	22,000
4AECR003.02	Elk Creek	63.6	7,900	3,300
4AECR007.62	Elk Creek	41.8	7,000	18,000
4AECR016.99	Elk Creek	22.1	1,200	1,100
4ABOR029.74	Big Otter River	205.0	2,100	7,900

[a] Sample was obtained from just below the stream surface.

[b] Stream bottom was stirred prior to sample collection.

5.2 Source Assessment of Fecal Coliform

Procedures used in quantifying fecal coliform sources are discussed in Section 2.6. Specific information for the Elk Creek watershed (L25) is presented in the following sections.

5.2.1 Point Source

The two permitted point sources in the Elk Creek watershed are Gunnoe Sausage Co. (VPDES Permit No. VA0001449) and Otter River Elementary School (VPDES Permit No. VA0020851) (Figure 2.3). Based on a monthly grab sampling interval, Gunnoe Sausage Co. is permitted to discharge an average fecal coliform concentration of 200 cfu/100 mL with a maximum concentration of 400 cfu/100 mL with no limitations on effluent volume. The Otter River Elementary School is required to chlorinate and is permitted to discharge fecal coliform at a rate of 200cfu/100mL.

5.2.2 Nonpoint Source

Nonpoint sources of fecal coliform in the Elk Creek watershed include humans, pets, livestock, and wildlife. Fecal coliform directly deposited in the stream by any source is characterized as a direct nonpoint source while fecal coliform applied or deposited on the land is termed as nonpoint source.

Humans

Using the procedure outlined in Section 2.6.2.1 of this report and based on an average household size of 2.5 persons, the Elk Creek watershed has an estimated total human population of 6,158. Distribution of human population among the subwatersheds is shown in Table 5.4.

Table 5.4. Distribution of human and pet populations in the Elk Creek watershed (L25)

Subwatershed	Human population	Pet population
2501	162	65
2502	37	15
2503	2,793	1,117
2504	408	163
2505	150	60
2506	895	358
2507	275	110
2508	1,438	575
Total	**6,158**	**2,463**

<u>Failing septic systems</u>

Based on an average household size of 2.5 persons and fecal coliform production of 1.95×10^9 cfu/day, a typical failing septic system contributes 4.88×10^9 cfu/day to the rural residential land use. The numbers of failing septic systems in the subwatersheds of Elk Creek are shown in Table 5.5.

<u>Biosolids</u>

No biosolids applications were made in the watershed from 1990-1998. As described in Chapter 3, the 1990-1998 period was considered in evaluating fecal coliform loading under existing conditions.

Table 5.5. Estimated number of unsewered households by age, number of failing septic systems, and straight pipes in the Elk Creek watershed (L25).

Subwater-shed	Unsewered houses by age (no.)				Failing septic systems (no.)	Straight pipes (no.)
	Pre-1967	1967-1985	Post-1985	Total		
2501	21	0	44	65	10	0
2502	15	0	0	15	6	0
2503	200	140	777	1,117	131	1
2504	49	58	56	163	33	0
2505	26	16	18	60	14	0
2506	103	102	153	358	66	0
2507	31	33	46	110	20	0
2508	166	114	295	575	98	0
Total	**611**	**463**	**1,389**	**2,463**	**378**	**1**

Straight pipes

A household with a straight pipe contributes 4.88×10^9 cfu/day (household size multiplied by daily fecal coliform production) directly into the stream. The numbers of straight pipes in the subwatersheds of Elk Creek are given in Table 5.5.

Pets

Based on the assumption of one pet per household, the number of pets in each subwatershed of Elk Creek was calculated (Table 5.4). There is no fecal coliform loading from pets to the high-density residential land use in this watershed because this land use is comprised of urban and built-up land without any residences. The entire pet loading is applied to the rural residential land use by multiplying the number of pets by the fecal coliform produced by a pet (450×10^6 cfu/day).

Livestock

Beef cattle

Beef cattle in the Elk Creek watershed were distributed among the subwatersheds based on their pasture acreages. The number of beef cattle in each subwatershed is shown in Table 5.6.

Table 5.6. Distribution of beef cattle, dairy cattle, and horses among the subwatersheds in the Elk Creek watershed (L25)

Subwatershed	Beef	Dairy[a]		Horses
		Pre-1996	Current	
2501	169	0	0	25
2502	159	0	0	23
2503	892	285	190	130
2504	316	315	210	46
2505	63	0	0	9
2506	634	0	0	92
2507	90	0	0	13
2508	1,087	0	100[b]	158
Total	**3,410**	**600**	**500**	**496**

[a] Includes milk cows, dry cows, and heifers

[b] Heifer herd

Dairy cattle

Distribution of dairy cattle among the subwatersheds is given in Table 5.6. As discussed in Section 2.6, the pre-1996 dairy numbers are based on 1987 and 1992 Agricultural Census and were used for the calibration simulations. The current dairy numbers were used for simulating the allocation scenarios.

Horses

Horses were distributed among the subwatersheds based on their pasture acreages. Distribution of horses among the subwatersheds is given in Table 5.6.

Direct manure deposition in streams

Manure deposition in streams is affected by the number of beef and dairy cattle in the watershed as well as the percent pasture acreage with stream access. The percentage of pasture with stream access in each subwatershed (Table 5.7) of Elk Creek was calculated using the procedure given in Section 2.6.

Table 5.7. Percentage of pasture with stream access in the subwatersheds of the Elk Creek watershed (L25)

Subwatershed	Percent of pasture with stream access
2501	49
2502	60
2503	26
2504	39
2505	52
2506	45
2507	28
2508	49
Average	**43**

While milk cows are confined part of the year, dry cows, heifers, and beef cattle are not confined. When not confined, milk cows as well as other cattle deposit their waste on pasture and stream. Monthly distribution of cattle in confinement, on pasture, and in streams in the Elk Creek watershed (Table 5.8) were calculated based on the confinement schedule for milk cows (Table 2.8), time spent by cattle in the stream (Table 2.8), and percent of pasture with stream access (Table 5.7). Cattle in the stream (Table 5.8) represent the number of cattle defecating in the stream, assuming that 30% of the cattle in and around the stream defecate in the stream.

Fecal coliform deposition in the stream by dairy and beef cattle was calculated by multiplying the number of cattle in the stream by fecal coliform production (Table 2.4). Total fecal coliform deposition was calculated by adding the fecal coliform production by the dairy and beef cattle defecating in the stream. Annual fecal coliform loadings to the streams in the subwatersheds of Elk Creek by dairy and beef cattle are given in Table 5.9.

Direct manure deposition on pastures

When not in confinement, cattle that do not deposit fecal coliform in the stream, contribute to fecal coliform loading on the pasture. Based on the monthly confinement schedule (Table 2.8) and stream access by subwatershed (Table 5.7), the number of dairy and beef cattle depositing fecal coliform on pasture are presented in Table 5.8. Total fecal coliform deposition on pasture was calculated by adding the fecal coliform production by the different types of cattle defecating on the pasture. Annual fecal coliform loading on the pastures in the subwatersheds of Elk Creek by dairy and beef cattle are given in Table 5.9.

Table 5.8. Monthly distribution of dairy and beef cattle among confinement, pasture, and stream in the Elk Creek watershed (L25)

Month	Dairy[a]			Beef		Total	
	Confined[b]	Pasture	Stream	Pasture	Stream	Dairy[a]	Beef
January	151 (101)	448 (398)	1 (1)	3,401	9	600 (500)	3,410
February	151 (101)	448 (398)	1 (1)	3,401	9	600 (500)	3,410
March	88 (59)	511 (440)	1 (1)	3,401	9	600 (500)	3,410
April	76 (50)	522 (448)	2 (2)	3,397	13	600 (500)	3,410
May	76 (50)	521 (448)	3 (2)	3,393	17	600 (500)	3,410
June	76 (50)	519 (445)	5 (5)	3,375	35	600 (500)	3,410
July	76 (50)	519 (445)	5 (5)	3,375	35	600 (500)	3,410
August	76 (50)	519 (445)	5 (5)	3,375	35	600 (500)	3,410
September	76 (50)	521 (448)	3 (2)	3,393	17	600 (500)	3,410
October	76 (50)	522 (448)	2 (2)	3,397	13	600 (500)	3,410
November	88 (59)	511 (440)	1 (1)	3,401	9	600 (500)	3,410
December	151 (101)	448 (398)	1 (1)	3,401	9	600 (500)	3,410

[a] Figures outside the parentheses represent pre-1996 numbers while the figures inside the parentheses represent current numbers.

[b] Only milk cows are confined.

Table 5.9. Annual fecal coliform loadings to stream and pasture by dairy and beef cattle in the subwatersheds of the Elk Creek watershed (L25)

Subwatershed	Stream ($\times 10^{12}$ cfu/year)		Pasture ($\times 10^{12}$ cfu/year)	
	Pre-1996	Current	Pre-1996	Current
2501	12.0	12.0	1,943	1,943
2502	14.5	14.5	1,916	1,916
2503	37.7	36.8	11,503	11,253
2504	26.7	24.0	5,393	4,852
2505	5.0	5.0	755	755
2506	43.2	43.2	7,631	7,631
2507	3.8	3.8	1,082	1,082
2508	81.0	83.6	13,036	13,454
Total	**223.9**	**222.9**	**43,259**	**42,886**

Land application of dairy manure

A typical milk cow weighs 1,400 lb and produces 17 gallons of liquid manure per day (ASAE, 1998). Hence, during the pre-1996 period, annual dairy manure production in confinement was estimated at 0.6 million gallons; current production was estimated to be 0.4 million gallons/year. There are two dairy operations in the Elk Creek watershed; one operation is located in subwatershed 2503 and the other in subwatershed 2504. It was assumed that all dairy manure produced in confinement was applied to cropland and pasture at 8,000 and 4,000 gallons/acre-year, respectively, within the subwatershed where it is produced. Currently, there is a heifer herd located in subwatershed 2508 but since heifers are not confined, there is no manure collected in that subwatershed. Based on the pre-1996 numbers, it was estimated that 8.5% and 0.3% of cropland and pasture in the watershed, respectively, received dairy manure as per the application schedule given in Table 2.10. Currently, it is estimated that 5.7% and 0.2% of cropland and pasture, respectively, receive dairy manure. Fecal coliform in stored manure is subject to die-off (discussion on storage capacity for dairy manure is given in Section 2.6). After accounting for die-off during storage (Section 3.4), fecal coliform loadings from dairy manure to cropland and pasture in subwatersheds 2503 and 2504 are given in Table 5.10.

Table 5.10. Annual fecal coliform loadings to cropland and pasture in subwatersheds 2503 and 2504 of the Elk Creek watershed (L25)

Subwatershed	Cropland ($\times 10^{12}$ cfu/year)		Pasture ($\times 10^{12}$ cfu/year)	
	Pre-1996	Current	Pre-1996	Current
2503	1.1	0.7	0.5	0.4
2504	2.1	1.4	1.0	0.7

Wildlife

Based on the animal density (animals/acre-habitat) and acreage of habitat (Section 2.6), the wildlife species were distributed among the subwatersheds of the Elk Creek watershed (Table 5.11). Depending on the wildlife species, an animal deposits part of its waste loading directly into the stream (Table 2.11) while the remainder is deposited on land. The waste that was deposited on land was distributed among the different Land use types that constituted the wildlife species habitat based on their percentages of the total habitat. Annual distribution of fecal coliform loading from wildlife waste between the stream and different Land use types is given in Table 5.12.

Table 5.11. Distribution of wildlife among the different subwatersheds of the Elk Creek watershed (L25)

Wildlife species	Subwatershed								Total
	2501	2502	2503	2504	2505	2506	2507	2508	
Deer	102	220	523	167	67	349	86	499	2,013
Raccoon	35	40	107	43	14	59	21	44	363
Muskrat	169	192	585	219	66	291	146	244	1,912
Beaver	17	19	59	22	7	29	15	24	192
Goose	9	19	45	14	6	30	7	43	173
Duck	4	8	20	6	3	13	3	19	76
Mallard	4	9	22	7	3	15	4	21	85
Wild Turkey	13	40	44	19	10	35	10	41	212

Table 5.12. Annual distribution of fecal coliform from wildlife among the different land use types and streams in the subwatersheds of the Elk Creek watershed (L25).

Subwater-shed	Annual fecal coliform loading ($\times 10^{12}$ cfu/year)						Total
	Stream	Cropland	Forest	High Density Residential	Pasture	Rural Residential	
2501	9.5	0.0	39.4	0.1	20.2	2.1	**71.3**
2502	17.8	0.0	80.1	0.0	47.8	0.1	**145.8**
2503	44.9	4.1	145.5	10.0	98.4	47.4	**350.3**
2504	14.5	1.3	67.9	1.7	24.1	3.4	**112.9**
2505	6.1	0.0	32.4	0.6	4.7	3.0	**46.8**
2506	28.6	2.1	145.8	0.4	45.9	7.5	**230.3**
2507	8.0	0.2	35.9	0.8	8.7	5.8	**59.4**
2508	38.2	4.6	147.9	2.0	102.6	24.1	**319.4**
Total	**167.6**	**12.3**	**694.9**	**15.6**	**352.4**	**93.4**	**1,336.2**

5.2.3 Summary: Contribution from All Sources

Based on the inventory of sources discussed in Sections 5.2.2.1 through 5.2.2.4, contribution of the different nonpoint sources to direct annual fecal coliform loading to the streams for both the pre-1996 and current conditions is given in Table 5.13. Distribution of annual fecal coliform loading from nonpoint sources among the different land use categories for both the pre-1996 and current conditions is also given in Table 5.13.

From Table 5.13, it is clear that nonpoint source loadings to the land surface are nearly 200 times larger than direct nonpoint source loadings to the streams, with pastures receiving more than 96% of the total fecal coliform load. It could be prematurely assumed that most of the fecal coliform loading in streams originates from upland sources, primarily, from pastures. However, other factors such as precipitation and proximity to streams also impact the amount of fecal coliform from upland areas that reaches the streams.

Table 5.13. Annual fecal coliform loadings to the stream and the various land use categories in the Elk Creek watershed (L25)

Source	Pre-1996		Current	
	Fecal coliform loading ($\times 10^{12}$ cfu/year)	Percent of total loading	Fecal coliform loading ($\times 10^{12}$ cfu/year)	Percent of total loading
Direct loading to streams				
Cattle in stream	137.0	0.5	138.8	0.5
Wildlife in stream	39.7	0.1	39.7	0.1
Straight pipes	1.8	<0.1	1.8	<0.1
Loading to land surfaces				
Commercial/industrial	0.67	<0.1	0.67	<0.1
Cropland	4.30	<0.1	3.95	<0.1
Forest	149.43	0.6	149.43	0.6
High density residential	4.71	<0.1	4.71	<0.1
Pasture	27,631.72	96.2	27,799.56	96.1
Rural residential	849.55	2.6	849.55	2.6
Total	**28,818.88**	**100.0**	**28,988.17**	**100.0**

5.3 Modeling Process

5.3.1 Introduction

The Elk Creek watershed has a total area of 42,880 acres and is located in the northeast portion of the BOR basin. The upper portions of the watershed are forested in the extreme north and include portions of Lynchburg, Virginia, in the northeast. Only a portion of the Elk Creek watershed drains to the impaired segment. Southern portions of the Elk Creek watershed drain directly to the BOR, while the remaining area drains to Elk Creek, which is a tributary to the BOR. Elk Creek is listed as impaired from its confluence with the BOR up to a location near the intersection of state roads 643 and 705. The drainage area of the impaired segment is 28,254 acres. The VADEQ monitoring station (4AECR003.02) is located 3 miles upstream of the confluence of Elk Creek and the BOR. Since no monitored flow records are available at this station or at any other point within the Elk Creek watershed, the hydrology parameter set developed during the BOR hydrology calibration was used for Elk Creek. The water quality parameters were calibrated to the observed data at the Elk Creek VADEQ monitoring station.

5.3.2 Selection of Subwatersheds

The Elk Creek watershed was subdivided into eight subwatersheds and eight reaches (Fig. 5.1) for modeling purposes. The subwatersheds and reaches were delineated based on the stream network, land use patterns and the presence of monitoring stations and point source discharges. A single permitted point source was located on Elk Creek watershed, but this discharge is not in the drainage area of the impaired stream segment.

5.3.3 Input Data

The HSPF model requires a wide variety of input data to describe hydrology, water quality, and land use characteristics of the watershed. The different types and sources of input data used to develop the TMDL for the Elk Creek watershed are discussed below.

Climatlogical Data

Hourly precipitation data were obtained from the National Climatic Data Center's (NCDC) cooperative weather station at Lynchburg Municipal Airport, located approximately 5 miles east of the watershed. A complete set of surface meteorological data and hourly precipitation data was available for the Lynchburg station. Detailed descriptions of the weather data and the procedure for converting the raw data into the required data set is described in Appendix B.

Hydrology Model Parameters

The hydrology parameters required by PWATER and IWATER were defined for every land use category for each subwatershed. For each reach, a function table (FTABLE) is required to describe the relationship between water depth, surface area, volume, and discharge (Donigian et al., 1995). These parameters were estimated by surveying representative channel cross-sections in each subwatershed. Hydrology parameters required for the PWATER, IWATER, HYDR, and ADCALC sub-modules are listed in Appendix B.1 of BASINS ver. 2.0 User's Manual (Lahlou et al., 1998). Parameters required as inputs for PQUAL, IQUAL, and GQUAL are given Appendix B.1 of BASINS ver. 2.0 User's Manual (Lahlou et al., 1998). Values for the parameters were estimated from local conditions when possible, otherwise the default parameters provided within

HSPF were used. Key HSPF parameters used in the Elk Creek simulations are listed in Table 5.14.

Land use

Virginia DCR identified 24 land uses in the BOR basin. As described in Chapter 2, the 24 land uses were consolidated into six categories based on hydrologic, waste application, and production characteristics (Table 2.2). The land use categories were assigned pervious/impervious percentages, which allowed a land use with both pervious and impervious fractions to be modeled using both the PERLND and IMPLND modules. Land use data were used to select several hydrology and water quality parameters for the simulations.

5.3.4 Model Calibration and Validation

The water quality component of HSPF was calibrated by comparing the simulated daily fecal coliform values with 22 fecal coliform samples collected by VADEQ between August 1993 and December 1998. The goodness of the calibration was evaluated visually using graphs of simulated and observed values. The HSPF fecal coliform parameters used in model calibration are presented in Table 5.14. Given the sparse amount of observed data, three criteria were used to assess the adequacy of the water quality calibration. The first was that the simulated concentrations were not consistently lower than the observed concentrations. This criteria assured that the simulation was not biased towards lower concentrations. The second criterion was that the simulated concentrations equaled or exceeded the capped concentrations (8000 cfu/100mL) of the observed values. This assured that the simulation sufficiently represents the transport of fecal coliform during intense surface runoff events. Finally, the third criterion was that the simulated concentrations followed the same general pattern as the observed across seasons and through the years.

The calibrated model output at VADEQ station 4AECR003.02 is shown with the observed data in Figure 5.3. The goodness of the calibration was evaluated visually using the simulated and observed values in Figure 5.3. The initial water quality parameters selected for Elk Creek were adequate with the exception of the pervious land segment wash-off factor (WSQOP), which was changed to 2.4 in/hr. The pervious surface wash-off parameter was 1.0 in/hr in Sheep Creek simulation. Other water quality parameters were identical to those in Sheep Creek. The HSPF fecal coliform parameters used in model calibration are summarized in Table 5.14. As shown in Figure 5.3, the calibrated HSPF water quality parameters fit the observed data for Elk Creek, very well. The fecal coliform concentrations predicted by the model represent both the low and high observed values and exceed the 8000 cfu/100mL "capped" observed values as required. The calibrated concentrations also followed the same general pattern as the observed data across seasons and through the years. In light of the limited data available for calibration and validation, and the degree that both the trends and range of the observed data are reflected by the model predictions, the calibrated parameter set appears reasonable for representing the watershed and for TMDL development purposes.

Table 5.14. Input parameters used in HSPF simulations for Elk Creek.

PARAMETER	DEFINITION	UNITS	RANGE OF VALVES TYPICAL		POSSIBLE		START	FINAL	FUNCTION OF…
PERLIND			MIN	MAX	MIN	MAX		CALIB.	
PWAT-PARM2									
FOREST	Fraction forest cover	none	0.00	0.5	0	0.95	0.0, 1.0	1.0 forest, 0.0 other	Forest cover
LZSN	Lower zone nominal soil moisture storage	inches	3	8	2	15	14.1	4.5-11.3[1]	Soil properties
INFILT	Index to infiltration capacity	in/hr	0.01	0.25	0.001	0.5	0.16	0.054-0.086[1]	Soil and cover conditions
LSUR	Length of overland flow	feet	200	500	100	700	300	300	Topography
SLSUR	Slope of overland flowplane	none	0.01	0.15	0.001	0.3	0.035	0.05	Topography
KVARY	Groundwater recession variable	1/in	0	3	0	5	0	0	Calibrate
AGWRC	Base groundwater recession	none	0.92	0.99	0.85	0.999	0.98	0.97	Calibrate
PWAT-PARM3									
PETMAX	Temp below which ET is reduced	deg. F	35	45	32	48	40	40	Climate, vegetation
PETMIN	Temp below which ET is set to zero	deg. F	30	35	30	40	35	35	Climate, vegetation
INFEXP	Exponent in infiltration equation	none	2	2	1	3	2	2	Soil properties
INFILD	Ratio of max/mean infiltration capacities	none	2	2	1	3	2	2	Soil properties
DEEPFR	Fraction of GW inflow to deep recharge	none	0	0.2	0	0.5	0.1	0	Geology
BASETP	Fraction of remaining ET from baseflow	none	0	0.05	0	0.2	0.02	0.0-0.02[1]	Riparian vegetation
AGWETP	Fraction of remaining ET from active GW	none	0	0.05	0	0.2	0	0	Marsh/wetlands ET
PWAT-PARM4									
CEPSC	Interception storage capacity	inches	0.03	0.2	0.01	0.4	0.1	monthly[1]	Vegetation
UZSN	Upper zone nominal soil moisture storage	inches	0.10	1	0.05	2	1.128	0.235-2.05[1]	Soil properties
NSUR	Mannings' n (roughness)	none	0.15	0.35	0.1	0.5	0.2	0.06-0.09[1]	Landuse, surface condition
INTFW	Interflow/surface runoff partition parameter	none	1	3	1	10	0.75	1.4	Soils, topography, land use
IRC	Interflow recession parameter	none	0.5	0.7	0.3	0.85	0.5	0.3	Soils, topography, land use
LZETP	Lower zone ET parameter	none	0.2	0.7	0.1	0.9	monthly	monthly[1]	Vegetation
QUAL-INPUT									
ACQOP	Rate of accumulation of constituent	#/day						monthly[1]	Land use
SQOLIM	Maximum accumulation of constituent	#						9 x ACQOP	Land use
WSQOP	Wash-off rate	in/hr						2.4	Land use
IOQC	Constituent conc. in interflow	$\#/ft^3$						2832	Land use

[1] Varies with land use

Table 5.14. Input parameters used in HSPF simulations for Elk Creek (Continued).

			RANGE OF VALVES						
PARAMETER	DEFINITION	UNITS	TYPICAL		POSSIBLE		START	FINAL	FUNCTION OF…
PERLIND			MIN	MAX	MIN	MAX		CALIB.	
AOQC	Constituent conc. in active groundwater	#/ft^3						1416	Land use
IMPLND									
IWAT-PARM2									
LSUR	Length of overland flow	feet	200	500	100	700	300	300	Topography
SLSUR	Slope of overland flowplane	none	0.01	0.15	0.001	0.3	0.035	0.01	Topography
NSUR	Mannings' n (roughness)	none	0.15	0.35	0.1	0.5	0.2	0.05	Land use, surface condition
RETSC	Retention/interception storage capacity	inches	0.03	0.2	0.01	0.4	0.1	0.065	Land use, surface condition
IWAT-PARM3									
PETMAX	Temp below which ET is reduced	deg. F	35	45	32	48	40	40	Climate, vegetation
PETMIN	Temp below which ET is set to zero	deg. F	30	35	30	40	35	35	Climate, vegetation
IQUAL									
ACQOP	Rate of accumulation of constituent	#/day						1.00E+07	Land use
SQOLIM	Maximum accumulation of constituent	#						3.00E+07	Land use
WSQOP	Wash-off rate	in/hr						1.8	Land use
RCHRES									
HYDR-PARM2									
KS	Weighting factor for hydraulic routing							0.5	
GQUAL									
FSTDEC	First order decay rate of the constituent	1/day						1.15	
THFST	Temperature correction coeff. for FSTDEC							1.05	

[1] Varies with land use

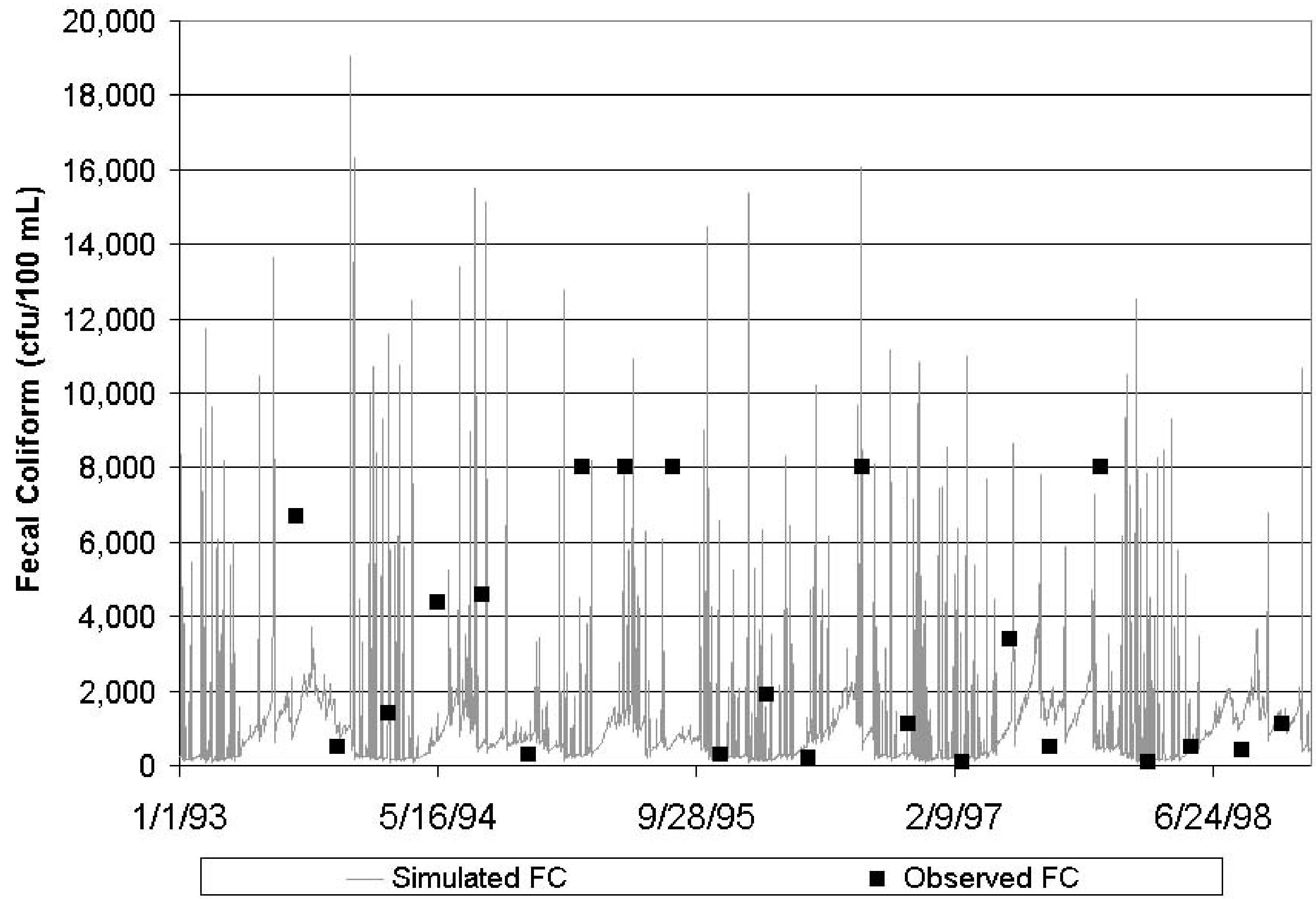

Figure 5.3. Simulated and observed fecal coliform concentrations for Elk Creek.

5.4 Load Allocations

5.4.1 Background

The objective of a TMDL is to allocate allowable loads among different pollutant sources so that the appropriate control actions can be taken to achieve water quality standards (USEPA, 1991). The objective of the TMDL for Elk Creek was to determine what reductions in fecal coliform loadings from point and nonpoint sources are required to meet state water quality standards. Since only a portion of the Elk Creek HU contributes runoff to the impaired Elk Creek stream segment, only four subwatersheds within the Elk Creek HU (2602, 2603, 2607, and 2608) contribute runoff and fecal coliform loads to the impaired segment (Figure 5.4). Although flow from Sheep Creek and North Otter Creek watersheds enters the Elk Creek HU via the BOR, the influence of these two watersheds was not considered in the Elk Creek TMDL modeling process because the flow from these two watersheds does not contribute to the impaired segment of Elk Creek. In developing the TMDL, water quality was simulated at four points (each stream segment in subwatersheds 2602, 2603, 2607, and 2608) and the final TMDL was developed for the stream reach that was the most restrictive (required the greatest reductions in loadings to meet the water quality standard). For the Elk Creek watershed, the most restrictive stream reach was located between the bridge of state road 643 (upstream end) and near the state road 668 bridge over Elk Creek (downstream end). The VADEQ monitoring station, 4AECR003.02, was also located on this stream segment.

The state water quality standard for fecal coliform used in the development of the TMDL was the 30-day geometric mean standard of 200 cfu/100mL. The TMDL considers all sources contributing fecal coliform to Elk Creek. The sources can be separated into nonpoint and point (or direct) sources. The incorporation of the different sources into the TMDL are defined in the following equation:

$$TMDL = WLA + LA + MOS \qquad [5.1]$$

where,

WLA	=	waste load allocation (point source contributions);
LA	=	load allocation (nonpoint source contributions); and
MOS	=	Margin of safety.

A MOS is included to account for uncertainty in the TMDL development process. There are several ways that the MOS can be incorporated into the TMDL (USEPA, 1991). For the Elk Creek TMDL, a margin of safety of 5% (i.e. MOS = 10 cfu/100mL) was used. By subtracting the MOS from the TMDL standard of 200 cfu/100mL, the goal of the TMDL allocation was that the combined point source (WLA) and NPS (LA) loads be below the target fecal coliform concentration (30-day geometric mean) of 190 cfu/100mL.

The time period selected for the calibration and load allocation was January 1, 1993 to December 31, 1998, the same as that used for the model calibration. This time period incorporates a wide range of hydrologic events including both low and high flow conditions.

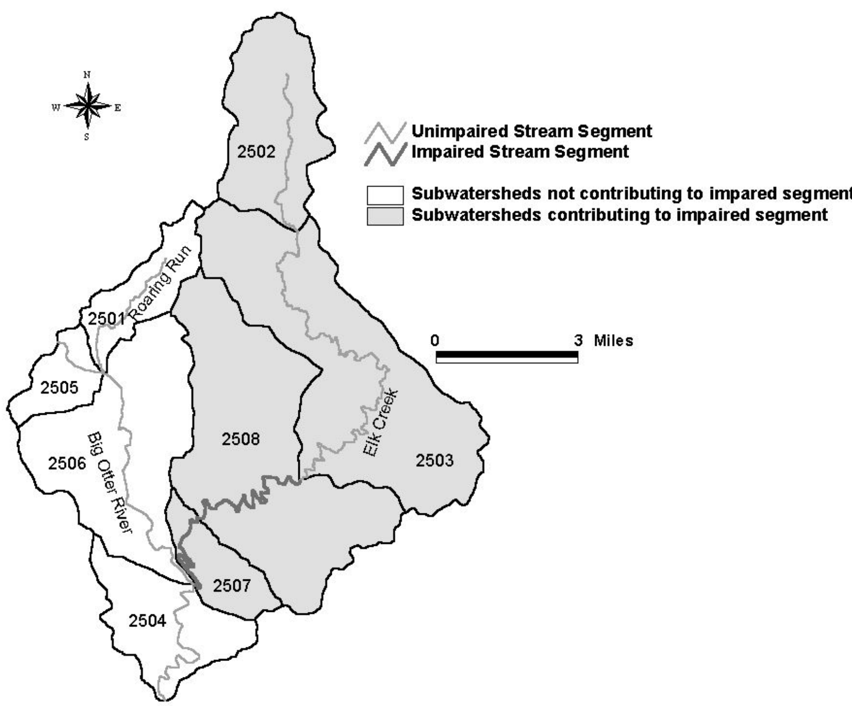

Figure 5.4. Elk Creek watershed showing subwatersheds contributing to the impaired segment.

5.4.2 Calibration Period and Existing Conditions

Analysis of the simulation results for the calibration period (Table 5.15) shows that fecal coliform loading from direct deposition by cattle is responsible for an average of 44% of the mean daily fecal coliform concentration in Elk Creek. Loads from PLS on average contribute about 44% of the mean daily fecal coliform concentration, while direct deposition from wildlife accounts for about 11%. The other sources, NPS loadings from impervious land segments (ILS), direct pipes, interflow, and groundwater together contribute less than 1% of the mean daily concentration.

Table 5.15. Relative contributions of different fecal coliform sources to the overall mean fecal coliform concentration for the calibration period.

Fecal Coliform Source	**Mean Daily Fecal Coliform Concentration Attributable to Source** (cfu/100mL)	**Relative Contribution by Source %**
Baseline -- All Sources	915	100
Direct Deposit from Cattle Only	406	44.4%
Direct Deposit from Wildlife Only	102	11.2%
Straight Pipe Discharge Only	4	0.4%
Loads from PLS Only	400	43.7%
Loads from ILS Only	0	0.0%
Contribution from Interflow and Groundwater	3	0.3%

The simulation of existing conditions provides the baseline for evaluating reductions required for the TMDL allocation. Cattle populations were reduced for the existing condition simulations, compared to the calibration period. The cattle population during the calibration period represented the average cattle populations in the watersheds from 1993 to 1998. The existing condition cattle populations account for the known decreases in dairy cattle populations during the last three to four years. Fecal coliform loads (NPS and direct NPS) used in the development of the TMDL allocation represent the cattle populations for "existing conditions". The calibrated hydrology and water quality parameter sets along with the best estimate of fecal coliform loads in the watershed were then used to simulate daily fecal coliform concentrations for the selected TMDL allocation study period of Jan 1, 1993 to Dec 31, 1998.

Table 5.16 gives the concentrations of fecal coliform for the existing conditions. Simulated 30-day mean fecal coliform concentrations in Elk Creek due to existing loads are shown in Figure 5.5 along with the geometric mean standard. Simulated concentrations are generally above the geometric mean standard. Exceptions occur during higher flow periods, generally between January and May.

Table 5.16. Existing condition fecal coliform loads for Elk Creek from direct NPS.

Source	Fecal coliform loading* ($\times 10^{12}$ cfu/year)	Percent of total loading
Cattle in stream	138.8	77.0
Wildlife in stream	39.7	22.0
Straight pipes	1. 8	1.0
Total	**180.5**	**100.0**

* Only loads from subwatersheds contributing to the impaired segment

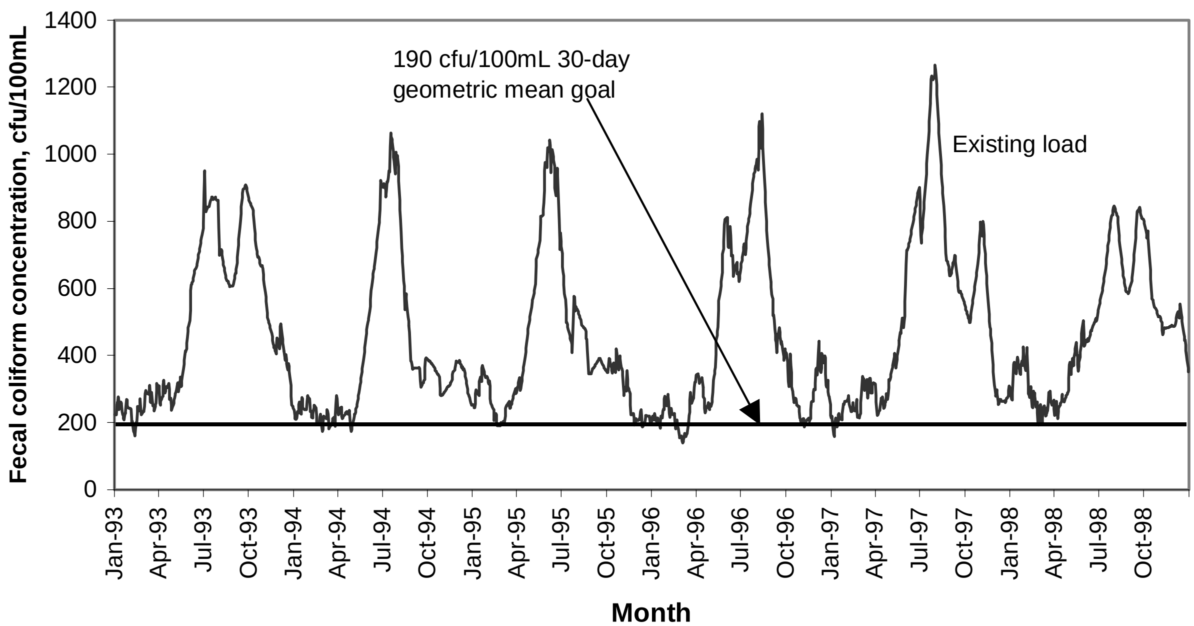

Figure 5.5. Simulated 30-day mean fecal coliform concentrations in Elk Creek (at VADEQ station 4AECR003.02) due to existing Elk Creek loads.

During low-flow conditions, when there is limited dilution, direct deposits by cattle are the primary source of fecal coliform loadings to the streams. This is especially critical during the summer when stream flow is generally lower and cattle spend more time in the streams. It is estimated that in the summer months, cattle spend two hours per day in the streams (Table 2.8). Hence, of the 1582 cattle on pastures with stream access, an equivalent of 132 cattle spend the entire day in the stream. It was estimated that 30% of the feces of these cattle is deposited directly into the streams, which is the equivalent of the waste from 40 cattle. This accounts for 2.5% of the manure load produced by the cattle on pastures with stream access. The fraction of manure directly deposited in the stream at other times of the year is lower, but can still contribute to exceeding the standard during low-flow periods.

5.4.3 Allocation Scenarios

Several allocation scenarios were evaluated to meet the 30-day geometric mean TMDL standard and MOS of 190 cfu/100mL. Scenarios 5 and 7 meet the TMDL allocation requirement of no violations of the 190 cfu/100mL 30-day geometric mean standard (Table 5.17). Scenario 5 was selected as the TMDL allocation plan since it allows a little flexibility in the reduction of direct deposition from cattle into streams. Loadings from straight pipes were reduced by 100% for all scenarios. It was obvious that reductions in direct deposition from cattle to streams had the greatest effect on reducing the concentration of fecal coliform in the impaired stream segment. When the reduction in direct deposition from cattle was only 50%, the percent exceedances of the 190 cfu/100mL goal was about 79%. However, the exceedances rate was 2% when the direct deposition from cattle was reduced by 95%. On the other hand, even complete elimination of direct deposition from cattle did not achieve the TMDL goal. Therefore, reductions had to be made in other sources including wildlife and loads from PLS. Direct deposition from wildlife was reduced by 70% and loads from PLS were reduced by 60% in the final TMDL allocation plan. (scenario 5). In combination, these reductions achieve the TMDL goal of zero exceedances of the 190 cfu/100mL geometric mean goal.

Table 5.18 shows the loads from NPS for all land uses and the results of the 60% reduction called for by the TMDL allocation plan (scenario 5 in Table 5.17). The reductions in direct NPS loads required by the TMDL allocation plan (scenario 5) are shown in Table 5.19. The graph of 30-day geometric mean fecal coliform concentrations for existing conditions and for the TMDL allocation scenario (scenario 5, Figure 5.6) shows that simulated concentrations do not exceed the geometric mean goal of 190 cfu/100mL during the allocation period.

Table 5.17. Fecal coliform TMDL allocation scenarios for Elk Creek

Scenario	Percent Reduction in Direct Deposit from Cattle	Percent Reduction in Direct Deposit from Wildlife	Percent Reduction in Straight Pipes	Percent Reduction in Loads from Pervious Agricultural Land Segments	Percent Exceedances of 190 cfu/100 mL Geometric Mean Goal
1	50	50	100	0	78.6
2	95	60	100	60	1.92
3	95	70	100	60	0.46
4	95	80	100	60	0.09
5*	**97**	**70**	**100**	**60**	**0.00**
6	100	50	100	30	1.60
7	100	60	100	60	0.00

*Bold indicates the scenario selected

Table 5.18. Annual NPS loads by land use to Elk Creek for existing conditions and required reductions for the TMDL allocation plan (scenario 5).

Pervious Land Segment Category	Existing Conditions		Allocation Scenario	
	Existing load* (x 10^{12} cfu)	Percent of total load to stream from NPS	TMDL NPS allocation load* (x 10^{12} cfu)	Percent reduction from existing load
Commercial/Industrial	0.01	< 0.1	0.01	0
Cropland	0.06	< 0.1	0.02	60
Forest	19.19	0.3	19.19	0
High Density Residential	0.39	< 0.1	0.39	0
Pasture	5,697.95	97.8	2,279.18	60
Rural Residential	106.71	1.8	106.71	0
Total	**5,824.31**	**100.0**	**2,405.50**	**58.7**

*Loads only from subwatersheds contributing to the impaired segment

Table 5.19. Annual direct NPS loads to Elk Creek for existing conditions and required reductions for the TMDL allocation plan (scenario 5).

Source	Existing Conditions		TMDL Allocation plan (scenario5)	
	Fecal coliform load* ($\times 10^{12}$ cfu/year)	Percent of total load to stream from direct NPS	NPS allocation load* ($\times 10^{12}$ cfu/year)	Percent reduction
Cattle in stream	138.8	77.0	4.2	97.0
Wildlife in stream	39.7	22.0	11.9	70.0
Straight pipes	1.8	1.0	0.0	100.0
Total	**180.3**	**100.0**	**16.1**	**91.1**

*Loads only from subwatersheds contributing to the impaired segment

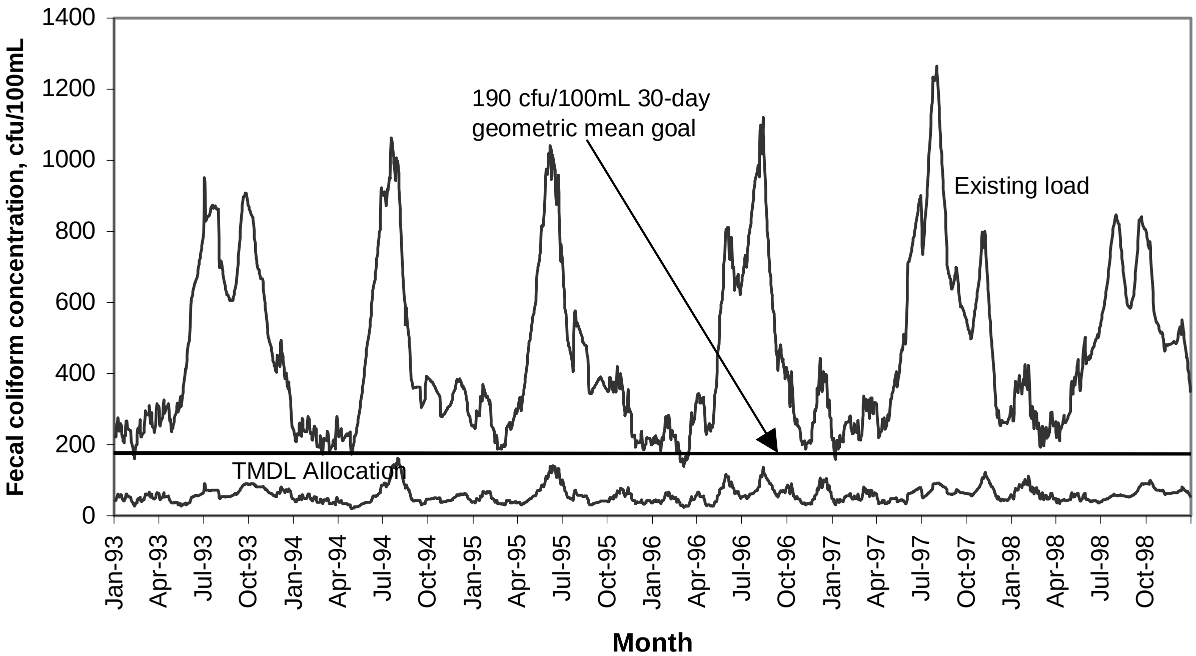

Figure 5.6. Successful TMDL allocation, 190 cfu/100mL 30-day geometric mean goal, and existing conditions (Scenario 5, Table 5.17).

5.4.4 Summary of TMDL Allocation

A TMDL allocation for fecal coliform has been developed for Elk Creek. The TMDL addresses the following issues.

1 The TMDL meets the water quality standard of no exceedances of the 30-day geometric mean fecal coliform concentration of 200 cfu/100 mL.

2 A MOS of 5% was incorporated in the development of the TMDL plan.

3 The TMDL accounts for fecal coliform from human, domestic/agricultural animals, and wildlife sources.

4 Both high- and low-flow stream conditions were considered in developing the TMDL. In the Elk Creek watershed, low flow conditions were found to be the environmental condition most likely to cause a violation of the 30-day geometric mean.

5 Both the flow regime and fecal coliform loadings are seasonal, with higher loadings and in-stream concentrations during the summer than in the winter. The TMDL accounts for these seasonal effects.

6 The TMDL allocation required to meet the 30-day geometric mean water quality goal of 190 cfu/100mL requires: a 97% reduction in direct deposits of cattle manure to streams, a 70% reduction in direct deposits by wildlife to streams, a 60% reduction in NPS loadings from pasture and cropland, and the elimination of straight pipes. The annual fecal coliform loads for the selected TMDL allocation scenario are summarized in Table 5.20.

Table 5.20. Annual fecal coliform allocation (cfu/year) for the Elk Creek watershed fecal coliform TMDL.

Subwatershed	Point Source Loads	Nonpoint Source Loads	Margin of Safety[a]	TMDL Annual Load
Elk Creek	$<0.1X10^{12}$	$2,421.6 \times 10^{12}$	127.5×10^{12}	$2,549.1 \times 10^{12}$

[a] Five percent of TMDL

6 TMDL FOR MACHINE CREEK WATERSHED

6.1 Watershed Characterization

6.1.1 Water Resources

The Machine Creek watershed (L26a) has 28.0 miles of primary and secondary streams. In addition to Machine Creek, the stream network in the watershed is comprised of Bunker Hill Creek, Nininger Creek, and Skinnels Creek, all of which drain into Machine Creek (Figure 6.1). At the outlet of the watershed, Machine Creek drains into the Little Otter River; further downstream, the Little Otter River confluences with the BOR. The watershed is located in the Piedmont physiographic province, with a moderate to low groundwater pollution potential (VWCB, 1985). Depth to the seasonal high water table in the watershed is generally greater than 6 ft below the mineral soil surface (SCS, 1989).

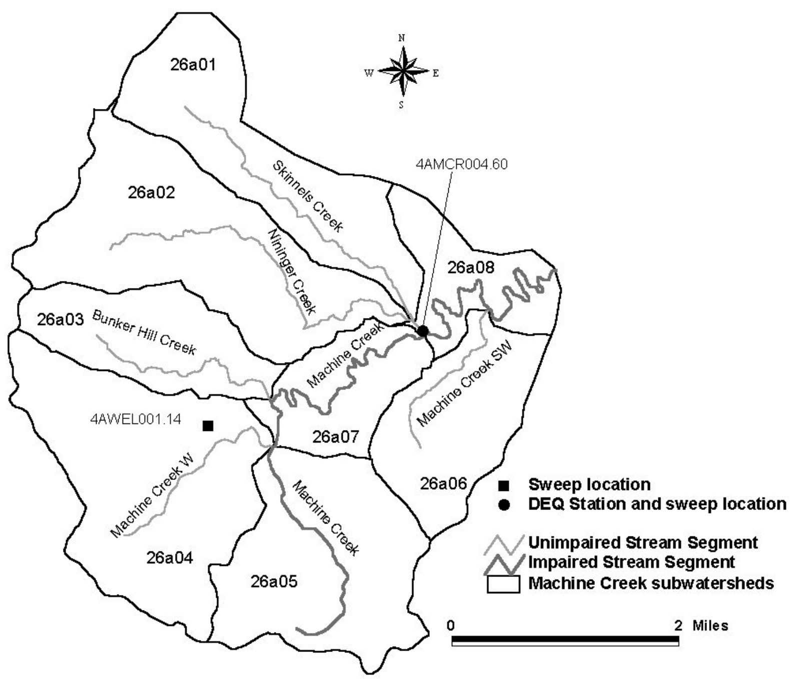

Figure 6.1. Machine Creek (L26a) subwatersheds, stream network, locations of VADEQ water quality monitoring sites and sweep sites for flow and water quality monitoring

6.1.2 Soils

The soil association found in the watershed is Cecil-Madison soils. A detailed description of this soil association is given in Section 2.5.2.

6.1.3 Land use

The watershed was divided into eight subwatersheds to spatially analyze fecal coliform distribution within the watershed (Figure 6.1). Land use distribution in the subwatersheds and the entire Machine Creek watershed is presented in Table 6.1. The watershed is mainly pasture (44.8%) and forest (41.2%).

Table 6.1. Land use distribution (acres) among the subwatersheds of the Machine Creek watershed (L26a)

Land use	Subwatershed								Total[a]	
	26a01	26a02	26a03	26a04	26a05	26a06	26a07	26a08	Acres	%
Commercial/ industrial	10	4	16	0	5	0	0	4	39	0.2
Cropland	143	80	19	114	111	174	168	285	1,094	6.0
Forest	803	1,702	605	1,191	1,354	746	743	399	7,543	41.2
High density residential	195	53	26	69	28	41	3	19	434	2.4
Pasture	1,185	1,550	1,000	2,069	1,029	790	305	274	8,202	44.8
Rural residential	180	64	10	175	264	70	21	198	982	5.4
Total[a]	**2,516**	**3,453**	**1,676**	**3,618**	**2,791**	**1,821**	**1,240**	**1,179**	**18,294**	**100.0**

[a] Component acreages may not add up due to round-off error.

6.1.4 Flow and Water Quality Data

Historic data

The VADEQ collected monthly water quality samples at monitoring site 4AMCR004.60 (Figure 6.1) from August 1992 until June 1996. No concomitant flow data were collected at the monitoring site. The water quality samples were analyzed for fecal coliform using the MFT with a maximum concentration cap of 8,000 cfu/100 mL. Even though most samples were collected at monthly intervals, in some cases, the sampling interval exceeded 3 months. Monitoring site 4AMCR004.60 is located on the impaired segment of Machine Creek, downstream of where Skinnels Creek and Nininger Creek confluence with Machine Creek (Figure 6.1). Time series data of fecal coliform concentration observed at 4AMCR004.60 are presented in Figure 6.2.

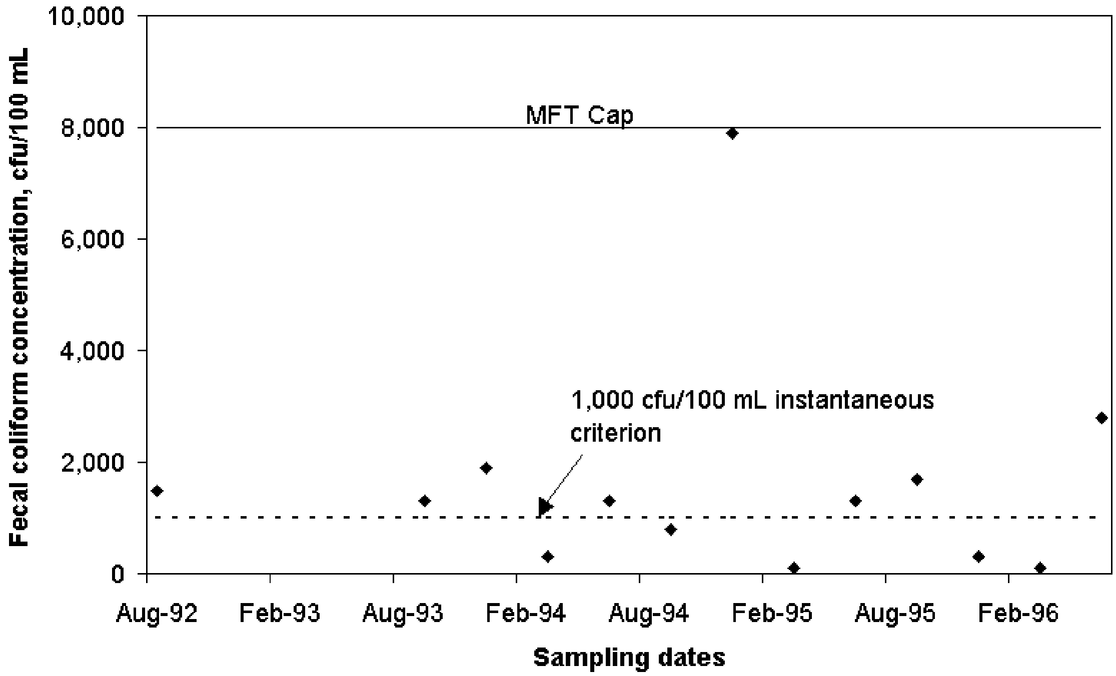

Figure 6.2. Time series of fecal coliform concentration observed at VADEQ monitoring station 4AMCR004.60 on Machine Creek.

More than 61% of the samples exceeded the instantaneous water quality standard of 1,000 cfu/100 mL. Given the irregular sampling interval, it is unclear if a seasonal fecal coliform trend exists. Further, given the lack of flow data, no inferences could be made regarding the impact of flow on fecal coliform concentration.

Water quality sweep and flow measurement

The VADEQ and Virginia Tech conducted a water quality and flow-monitoring sweep on March 20-22, 2000. The purpose of the sweep was to assess water quality conditions at various stations within the Machine Creek watershed. The following factors were considered in selecting the monitoring sites for conducting the sweep.

- Water quality at the monitoring site should be representative of the impact of Land use practices immediately upstream of the site;

- the monitoring site should be in close proximity to a road or bridge so that the site would be located on public land with easy access; and

- the monitoring site should be located at the outlet of the subwatershed.

Two monitoring sites were selected that met the criteria. The sites are described in Table 6.2 and their locations are indicated in Figure 6.1. Wells Creek, the stream on which monitoring site 4AWEL001.14 is located, is not shown in Figure 6.1.

Table 6.2. Location and description of sampling sites for instantaneous water quality and flow assessment

ID	Stream	Location
4AWEL001.14	**Wells Creek**	**Bridge on Rt. 722 south of intersection of Rt. 722 and Rt. 747**
4AMCR004.60	**Machine Creek**	**Bridge on Rt. 804 near intersection of Rt. 804 and Rt. 724, upstream from confluence of Machine Creek and Nininger Creek.**

At each site, staff from VADEQ collected two water samples, one from below the stream surface and another at the bottom of the stream (after disturbing the streambed). Samples were stored on ice and were analyzed for fecal coliform within 24 hours using the MPN method by the DCLS in Richmond. The MPN method used a maximum detection limit of 160,000 cfu/100 mL. Flow rate was calculated by multiplying the flow velocity (measured with a current meter) with the measured channel cross-sectional area. The results of the sweep are presented in Table 6.3.

Table 6.3. Results of the instantaneous fecal coliform and flow assessment

ID	Stream	Flow (cfs)	Fecal coliform counts (cfu/100 mL)	
			Stream surface[a]	Stream bottom[b]
4AWEL001.14	**Wells Creek**	1.94	22,000	22,000
4AMCR004.60	**Machine Creek**	48.90	160,000[c]	160,000[c]

[a] Sample was obtained from just below the stream surface.

[b] Stream bottom was stirred prior to sample collection.

[c] Upper limit of detection

In the seven days preceding the sweep, a total of 1.67 inches of precipitation was recorded at Lynchburg Regional Airport with 1.17 inches of the amount recorded in the preceding 48 hours. Fecal coliform concentrations in the stream surface and bottom samples exceeded the instantaneous standard at both sites. Fecal coliform concentrations in both the stream surface and bottom samples were higher close to the watershed outlet (4AMCR004.60) than at the headwaters (4AWEL001.14). Since the fecal coliform concentrations in both the surface and bottom samples at 4AMCR004.60 were at the 160,000-cap level, actual fecal coliform concentrations could have been higher.

6.2 Source Assessment of Fecal Coliform

Procedures used in quantifying fecal coliform sources are discussed in Section 2.6. Specific information for the Machine Creek watershed is presented in the following sections.

6.2.1 Point Source

The sole permitted point source in the Machine Creek watershed is the Body Camp Elementary School (VPDES Permit No. VA0020818), located on the southwestern boundary of the watershed (Figure 2.3). The school is required to chlorinate and permitted to discharge fecal coliform at a rate of 200cfu/100mL.

6.2.2 Nonpoint Source

Nonpoint sources of fecal coliform in the Machine Creek watershed include humans, pets, livestock, and wildlife. Fecal coliform directly deposited in the stream by any source is characterized as a direct nonpoint source while fecal coliform applied or deposited on the land is termed as nonpoint source.

Humans

Based on an average household size of 2.5 persons per household, the Machine Creek watershed has an estimated total human population of 2,303. Distribution of human populations among the subwatersheds is shown in Table 6.4.

Table 6.4. Distribution of human and pet populations in the Machine Creek watershed (L26a)

Subwatershed	Human population	Pet population
26a01	865	346
26a02	320	128
26a03	110	44
26a04	358	143
26a05	288	115
26a06	175	70
26a07	27	11
26a08	160	64
Total	**2,303**	**921**

Failing septic systems

Based on an average household size of 2.5 persons and a fecal coliform production of 1.95 $\times$ 10^9 cfu/day, a typical failing septic system contributes 4.88 $\times$ 10^9 cfu/day to the rural residential Land use. The numbers of failing septic systems in the subwatersheds of Machine Creek are shown in Table 6.5.

Table 6.5. Estimated number of unsewered households by age, number of failing septic systems, and straight pipes in the Machine Creek watershed (L26a)

Subwater -shed	Unsewered houses by age (no.)				Failing septic systems (no.)	Straight pipes (no.)
	Pre-1967	1967-1985	Post-1985	Total		
26a01	46	63	44	153	32	0
26a02	44	47	37	128	28	0
26a03	23	10	11	44	12	0
26a04	54	33	56	143	30	0
26a05	55	35	25	115	30	0
26a06	25	24	21	70	15	0
26a07	4	12	13	29	4	0
26a08	22	12	12	46	12	0
Total	**273**	**236**	**219**	**728**	**163**	**0**

Biosolids

During 1990-1998, five subwatersheds, 26a01, 26a02, 26a03, 26a04, 26a06 (Figure 6.1) received biosolids. Based on information provided by VADEQ and VDH, biosolids applications to cropland and pasture during this period are shown in Table 6.6. As described in Chapter 3, the 1990-1998 period was considered in evaluating fecal coliform loading under existing conditions.

Table 6.6. Average monthly fecal coliform loading ($\times$ 10^9 cfu/month) from biosolids application in the five subwatersheds (26a01, 26a02, 26a03, 260a4, and 26a06) of the Machine Creek watershed (L26a)

Month	26a01			26a02						26a03			26a04			26a06		
	Pasture			Cropland			Pasture			Pasture			Pasture			Cropland		
	Area (ac)	Appl. rate 1[a]	Appl. rate 2[b]	Area (ac)	Appl. rate 1[a]	Appl. rate 2[b]	Area (ac)	Appl. rate 1[a]	Appl. rate 2[b]	Area (ac)	Appl. rate 1[a]	Appl. rate 2[b]	Area (ac)	Appl. rate 1[a]	Appl. rate 2[b]	Area (ac)	Appl. rate 1[a]	Appl. rate 2[b]
12/90	-	-	-	18	10.6	0.97	8	4.1	0.4	11	3	0.3	-	-	-	-	-	-
4/91	-	-	-	-	-	-	-	-	-	15	10.4	0.95	-	-	-	-	-	-
5/91	-	-	-	68	1.3	0.12	69	5.6	0.5	57	4.1	0.4	-	-	-	-	-	-
6/91	-	-	-	-	-	-	-	-	-	57	6.1	0.6	-	-	-	-	-	-
7/91	-	-	-	-	-	-	30	7.7	0.7	-	-	-	-	-	-	-	-	-
6/93	-	-	-	-	-	-	-	-	-	-	-	-	94	9.3	0.9	-	-	-
7/93	-	-	-	-	-	-	-	-	-	-	-	-	76	3.6	0.4	-	-	-
6/98	-	-	-	-	-	-	-	-	-	-	-	-	27	3.3	0.3	-	-	-
7/98	-	-	-	-	-	-	-	-	-	-	-	-	165	7.2	0.7	-	-	-
8/98	-	-	-	-	-	-	-	-	-	-	-	-	135	4.4	0.5	-	-	-

[a] Dry tons/acre
[b] Billion cfu/ac

<u>Straight pipes</u>

A household with a straight pipe contributes 4.88×10^9 cfu/day (household size multiplied by daily fecal coliform production) directly into the stream. It is estimated that there is no straight pipes in the Machine Creek watershed (Table 6.5).

Pets

Based on the assumption of one pet per household, the number of pets in each subwatershed of Machine Creek was calculated (Table 6.4). Fecal coliform loading from pets is distributed between the rural residential and high-density residential land uses based on the number of pets in each land use. Pet loading is applied to each of the two land uses by multiplying the number of pets by the fecal coliform produced by a pet (450×10^6 cfu/day) in that land use.

Livestock

Beef cattle

Beef cattle in the Machine Creek watershed (L26a) were distributed among the subwatersheds based on their pasture acreages. The number of beef cattle in each subwatershed is shown in Table 6.7.

Table 6.7. Distribution of beef cattle and horses among the subwatersheds in the Machine Creek watershed (L26a)

Subwatershed	Beef	Horses
26a01	212	29
26a02	277	38
26a03	178	25
26a04	369	51
26a05	184	25
26a06	141	19
26a07	54	8
26a08	49	7
Total	**1,464**	**202**

Dairy cattle

There are no dairy cattle in the Machine Creek watershed.

Horses

Horses were distributed among the subwatersheds based on their pasture acreages. Distribution of horses among the subwatersheds is given in Table 6.7.

Direct manure deposition in streams

Manure deposition in streams is affected by the number of beef cattle in the watershed as well as the percent pasture acreage with stream access. The percentage of pasture with stream access in each subwatershed (Table 6.8) of Machine Creek was calculated using the procedure given in Section 2.6.

Table 6.8. Percentage of pasture with stream access in the subwatersheds of the Machine Creek watershed (L26a)

Subwatershed	Percent of pasture with stream access
26a01	53
26a02	41
26a03	83
26a04	71
26a05	53
26a06	49
26a07	34
26a08	39
Average	**53**

Since beef cattle are not confined, they deposit their waste on pasture and into streams. Monthly distribution of beef cattle on pasture and in streams in the Machine Creek watershed (Table 6.9) were calculated based on the time spent by cattle in the stream (Table 2.8) and percent of pasture with stream access (Table 6.8). Cattle in the stream (Table 6.9) represent the number of cattle defecating in the stream, assuming that 30% of the cattle in and around the stream defecate in the stream.

Fecal coliform deposition in the stream by beef cattle was calculated by the multiplying the number of cattle in the stream by the fecal coliform production (Table 2.4). Annual fecal coliform loadings to the streams in the subwatersheds of Machine Creek by beef cattle are given in Table 6.10.

Table 6.9. Monthly distribution of beef cattle between pastures and stream in the Machine Creek watershed (L26a)

Month	Number of cattle		
	Pasture	Stream	Total
January	1,459	5	1,464
February	1,459	5	1,464
March	1,459	5	1,464
April	1,456	8	1,464
May	1,454	10	1,464
June	1,443	21	1,464
July	1,443	21	1,464
August	1,443	21	1,464
September	1,454	10	1,464
October	1,456	8	1,464
November	1,459	5	1,464
December	1,459	5	1,464

Table 6.10. Annual fecal coliform loadings to stream and pasture by beef cattle in the subwatersheds of the Machine Creek watershed (L26a)

Subwatershed	Stream	Pasture
	($\times 10^{12}$ cfu/year)	
26a01	16.8	2,517
26a02	17.3	3,361
26a03	21.8	2,078
26a04	40.1	4,473
26a05	14.9	2,229
26a06	10.0	1,619
26a07	2.7	649
26a08	2.9	588
Total	**126.5**	**17,514**

Direct manure deposition on pastures

Based on stream access by subwatershed (Table 6.8), the number of beef cattle depositing fecal coliform on pastures is presented in Table 6.9. Fecal coliform deposition on pasture was calculated by multiplying the number of cattle on pasture by the fecal coliform production (Table 2.4). Annual fecal coliform loading on the pastures in the subwatersheds of Machine Creek by the beef cattle is given in Table 6.10.

Land application of dairy manure

Since there are no dairy cattle in the watershed, no manure is collected for land application.

Wildlife

Based on the animal density (animals/acre-habitat) and acreage of habitat (Section 2.6), the wildlife species were distributed among the subwatersheds of the Machine Creek watershed (Table 6.11). Depending on the wildlife species, an animal deposits part of its waste loading directly into the stream (Table 2.11) while the remainder is deposited on land. The waste that was deposited on land was distributed among the different land use types that constituted the wildlife species habitat based on their percentages of the total habitat. Annual distribution of fecal coliform loading from wildlife waste between the stream and different land use types is given in Table 6.12.

Table 6.11. Distribution of wildlife among the subwatersheds of the Machine Creek watershed (L26a)

Wildlife species	Subwatersheds								Total
	26a01	26a02	26a03	26a04	26a05	26a06	26a07	26a08	
Deer	117	162	77	170	131	84	58	55	854
Raccoon	23	40	48	27	26	31	28	42	265
Muskrat	105	196	235	131	121	146	180	245	1,359
Beaver	19	23	13	12	14	11	20	23	135
Goose	10	14	7	15	11	7	5	5	74
Duck	5	6	3	7	5	3	2	2	33
Mallard	5	7	3	7	6	4	3	2	37
Wild Turkey	8	17	6	12	14	7	7	4	75

6.2.3 Summary: Contribution from All Sources

Based on the inventory of sources discussed in Sections 6.2.2.1 through 6.2.2.4, contribution of the different nonpoint sources to direct annual fecal coliform loading to the streams for both the pre-1996 and current conditions is given in Table 6.13. Distribution of annual fecal coliform loading from nonpoint sources among the different land use categories is also given in Table 6.13.

Table 6.12. Annual distribution of fecal coliform from wildlife among the different land use types and streams in the subwatersheds of the Machine Creek watershed (L26a)

Subwater-shed	Annual fecal coliform loading ($\times 10^9$ cfu/year)						Total
	Stream	Cropland	Forest	High Density Residential	Pasture	Rural Residential	
26a01	10.1	2.7	38.2	0.4	26.0	1.6	**79.0**
26a02	14.2	10.2	44.0	0.9	39.6	1.1	**110.0**
26a03	8.8	1.8	23.0	0.4	24.6	0.2	**58.8**
26a04	14.0	1.9	35.7	1.1	56.9	2.8	**112.4**
26a05	11.2	1.9	30.4	0.5	40.1	4.3	**88.4**
26a06	8.1	2.9	24.1	0.7	22.6	1.2	**59.6**
26a07	14.0	14.1	44.0	0.1	15.6	1.2	**89.0**
26a08	7.2	11.8	14.0	0.4	7.2	3.5	**44.1**
Total	**87.6**	**47.3**	**253.4**	**4.5**	**232.6**	**15.9**	**641.3**

Table 6.13. Annual fecal coliform loadings to the stream and the various land use categories in the Machine Creek watershed (L26a)

Source	Fecal coliform loading ($\times 10^{12}$ cfu/year)	Percent of total loading
Direct loading to streams		
Cattle in stream	126.6	0.7
Wildlife in stream	31.9	0.17
Straight pipes	0	0.0
Loading to land surfaces		
Commercial/industrial	0.15	<0.1
Cropland	17.25	0.09
Forest	92.41	0.50
High density residential	33.33	0.18
Pasture	17,655.81	96.04
Rural residential	425.45	2.31
Total	**18,382.9**	**100.0**

From Table 6.13, it is clear that nonpoint source loadings to the land surface are more than 100 times larger than direct nonpoint source loadings to the streams, with pastures receiving more than 96% of the total fecal coliform load. It could be prematurely assumed that most of the fecal coliform loading in streams originates from upland sources, primarily, from pastures. However, other factors such as precipitation, die-off, and proximity to streams also impact the amount of fecal coliform from upland areas that reaches the streams.

6.3 Modeling Process

6.3.1 Introduction

The 18,294 acre Machine Creek watershed is located in the west central portion of the BOR basin. The two principal land uses are forest and pasture with small amounts of cropland and residential land use. Machine Creek is impaired from its headwaters starting near Body Camp, Virginia at the junction of State Highways 722 and 725 to its confluence with the Little Otter River north of Otter Hill, Virginia and near the junction of State Highways 714 and 715. The VADEQ has one monitoring station (4AMCR004.60) located on Machine Creek. Since no monitored flow data was available at this station or at any other point within the Machine Creek watershed, the hydrology parameter set developed during the BOR hydrology calibration was used for Machine Creek. The HSPF water quality parameters were calibrated to give the best fit to the observed data at the VADEQ monitoring station.

6.3.2 Selection of Subwatersheds

The Machine Creek watershed was subdivided into eight subwatersheds and 11 reaches (Fig.6.1) for modeling purposes. The subwatersheds and reaches were delineated based on the stream network, land use patterns and the presence of monitoring stations and point source discharges. There was one permitted point source, Body Camp Elementary School in the Machine Creek watershed. No direct NPS discharges due to direct pipes from on-site wastewater disposal systems were identified or simulated.

6.3.3 Input Data

The HSPF model requires a wide variety of input data to describe hydrology, water quality, and Land use characteristics of the watershed. The different types and sources of input data used to develop the TMDL for the Machine Creek watershed are discussed below.

Climatological Data

Hourly precipitation data were obtained from the National Climatic Data Center's (NCDC) cooperative weather station at Lynchburg Municipal Airport, located approximately 10 miles to the east of the watershed. A complete set of surface meteorological data and hourly precipitation data was available for the Lynchburg station. Detailed descriptions of the weather data and the procedure for converting the raw data into the required data set is described in Appendix B.

Hydrology Model Parameters

The hydrology parameters required by PWATER and IWATER were defined for every land use category for each subwatershed. For each reach, a function table (FTABLE) is required to describe the relationship between water depth, surface area, volume, and discharge (Donigian et al., 1995). These parameters were estimated by surveying representative channel cross-sections in each subwatershed. Hydrology parameters required for the PWATER, IWATER, HYDR, and ADCALC sub-modules are listed in Appendix B.1 of BASINS ver. 2.0 User's Manual (Lahlou et al., 1998). Parameters required as inputs for PQUAL, IQUAL, and GQUAL are given Appendix B.1 of BASINS ver. 2.0 User's Manual (Lahlou et al., 1998). Values for the parameters were estimated based on local conditions when possible, otherwise the default parameters provided within HSPF were used. Key HSPF parameters used in the Machine Creek simulations are listed in Table 6.14.

Land use

Virginia DCR identified 24 land uses in the BOR basin. As described in Chapter 2, the 24 land uses were consolidated into six categories based on hydrologic, waste application, and production characteristics (Table 2.2). The land use categories were assigned pervious/impervious percentages, which allowed a land use with both pervious and impervious fractions to be modeled using both the PERLND and IMPLND modules. Land use data were used to select several hydrology and water quality parameters for the simulations.

6.3.4 Model Calibration and Validation

The water quality component of HSPF was calibrated by comparing the simulated daily fecal coliform values with 12 quarterly Machine Creek fecal coliform samples collected between

1993 and 1996 at the VADEQ monitoring station 4AMCR004.60 located upstream of the confluence of Nininger Creek and Machine Creek. Although 13 water quality samples were taken between August 1992 and June 1996 (Figure 6.2) only the 12 samples falling within the calibration period were used. The goodness of the calibration was evaluated visually using graphs of simulated and observed values. Given the sparse amount of observed data, only three simple criteria were used for the water quality calibration. The first was that the simulated concentrations were not consistently lower than the observed concentrations. This criteria assured that the simulation was not biased to lower concentrations. The second criterion was that the simulated concentrations be near or exceed the observed capped concentrations (8000 cfu/100mL), as much as possible. However, since there were very few observed fecal coliform concentrations spread over the time period simulated, it is possible that there could be significant discrepancies between the simulated and the observed fecal coliform concentration data. This assured that the simulation sufficiently represent the transport of fecal coliform during intense runoff events. Finally, the third criterion was that the simulated concentrations followed the same general pattern as the observed across seasons and through the years.

The initial water quality parameters selected for Machine Creek were adequate and parameter adjustment through calibration was not required. Water quality parameters were the same as those used in the Elk Creek watershed. The only differences between Sheep Creek, Elk Creek, and Machine Creek water quality parameters were the pervious land wash-off factor (WSQOP), which was 1.0 in/hr Sheep Creek and 1.8in/hr in Machine Creek and 2.4 in/hr in Elk Creek. Other HSPF fecal coliform parameters used in model calibration are presented in Table 6.14.

The calibrated model output at the VADEQ station is shown with the observed data in Figure 6.3. The fecal coliform concentrations predicted by the model represent the low and high range of observed values, exceeding at times the 8000 cfu "capped" sample values as should be expected. The simulated fecal coliform concentrations did not exceed the single capped observed value of 8000cfu/100mL. This is considered acceptable for two reasons. First, the simulated average daily fecal coliform concentrations are being compared to the instantaneous values. One would expect the simulated daily average concentrations to not always be greater than the instantaneous observations, due to the inherent variability in fecal coliform concentrations throughout the day. Secondly, it is not prudent to calibrate a model for a single value at the expense of all other observed values. In light of the very limited data available for calibration and validation, and to the degree that both the trends and range of the observed data are reflected by the model predictions, the calibrated parameter set appears reasonable for representing the watershed.

Table 6.14. Input parameters used in HSPF simulations for Machine Creek.

			RANGE OF VALVES						
PARAMETER	**DEFINITION**	**UNITS**	**TYPICAL**		**POSSIBLE**		**START**	**FINAL**	**FUNCTION OF…**
PERLIND			**MIN**	**MAX**	**MIN**	**MAX**		**CALIB.**	
PWAT-PARM2									
FOREST	Fraction forest cover	none	0.00	0.5	0	0.95	0.0, 1.0	1.0 forest, 0.0 other	Forest cover
LZSN	Lower zone nominal soil moisture storage	inches	3	8	2	15	14.1	4.5-11.3[1]	Soil properties
INFILT	Index to infiltration capacity	in/hr	0.01	0.25	0.001	0.5	0.16	0.054-0.086[1]	Soil and cover conditions
LSUR	Length of overland flow	feet	200	500	100	700	300	300	Topography
SLSUR	Slope of overland flowplane	none	0.01	0.15	0.001	0.3	0.035	0.05	Topography
KVARY	Groundwater recession variable	1/in	0	3	0	5	0	0	Calibrate
AGWRC	Base groundwater recession	none	0.92	0.99	0.85	0.999	0.98	0.97	Calibrate
PWAT-PARM3									
PETMAX	Temp below which ET is reduced	deg. F	35	45	32	48	40	40	Climate, vegetation
PETMIN	Temp below which ET is set to zero	deg. F	30	35	30	40	35	35	Climate, vegetation
INFEXP	Exponent in infiltration equation	none	2	2	1	3	2	2	Soil properties
INFILD	Ratio of max/mean infiltration capacities	none	2	2	1	3	2	2	Soil properties
DEEPFR	Fraction of GW inflow to deep recharge	none	0	0.2	0	0.5	0.1	0	Geology
BASETP	Fraction of remaining ET from baseflow	none	0	0.05	0	0.2	0.02	0.0-0.02[1]	Riparian vegetation
AGWETP	Fraction of remaining ET from active GW	none	0	0.05	0	0.2	0	0	Marsh/wetlands ET
PWAT-PARM4									
CEPSC	Interception storage capacity	inches	0.03	0.2	0.01	0.4	0.1	monthly[1]	Vegetation
UZSN	Upper zone nominal soil moisture storage	inches	0.10	1	0.05	2	1.128	0.235-2.05[1]	Soil properties
NSUR	Mannings' n (roughness)	none	0.15	0.35	0.1	0.5	0.2	0.06-0.09[1]	Landuse, surface condition
INTFW	Interflow/surface runoff partition parameter	none	1	3	1	10	0.75	1.4	Soils, topography, land use
IRC	Interflow recession parameter	none	0.5	0.7	0.3	0.85	0.5	0.3	Soils, topography, land use
LZETP	Lower zone ET parameter	none	0.2	0.7	0.1	0.9	monthly	monthly[1]	Vegetation
QUAL-INPUT									
ACQOP	Rate of accumulation of constituent	#/day						monthly[1]	Land use
SQOLIM	Maximum accumulation of constituent	#						9 x ACQOP	Land use
WSQOP	Wash-off rate	in/hr						1.8	Land use
IOQC	Constituent conc. in interflow	$\#/ft^3$						2832	Land use

[1] Varies with land use

Table 6.14. Input parameters used in HSPF simulations for Machine Creek (Continued).

			RANGE OF VALVES						
PARAMETER	**DEFINITION**	**UNITS**	**TYPICAL**		**POSSIBLE**		**START**	**FINAL**	**FUNCTION OF…**
PERLIND			**MIN**	**MAX**	**MIN**	**MAX**		**CALIB.**	
AOQC	Constituent conc. in active groundwater	$\#/ft^3$						1416	Land use
IMPLND									
IWAT-PARM2									
LSUR	Length of overland flow	feet	200	500	100	700	300	300	Topography
SLSUR	Slope of overland flowplane	none	0.01	0.15	0.001	0.3	0.035	0.01	Topography
NSUR	Mannings' n (roughness)	none	0.15	0.35	0.1	0.5	0.2	0.05	Land use, surface condition
RETSC	Retention/interception storage capacity	inches	0.03	0.2	0.01	0.4	0.1	0.065	Land use, surface condition
IWAT-PARM3									
PETMAX	Temp below which ET is reduced	deg. F	35	45	32	48	40	40	Climate, vegetation
PETMIN	Temp below which ET is set to zero	deg. F	30	35	30	40	35	35	Climate, vegetation
IQUAL									
ACQOP	Rate of accumulation of constituent	#/day						1.00E+07	Land use
SQOLIM	Maximum accumulation of constituent	#						3.00E+07	Land use
WSQOP	Wash-off rate	in/hr						1.8	Land use
RCHRES									
HYDR-PARM2									
KS	Weighting factor for hydraulic routing							0.5	
GQUAL									
FSTDEC	First order decay rate of the constituent	1/day						1.15	
THFST	Temperature correction coeff. for FSTDEC							1.05	

[1] Varies with land use

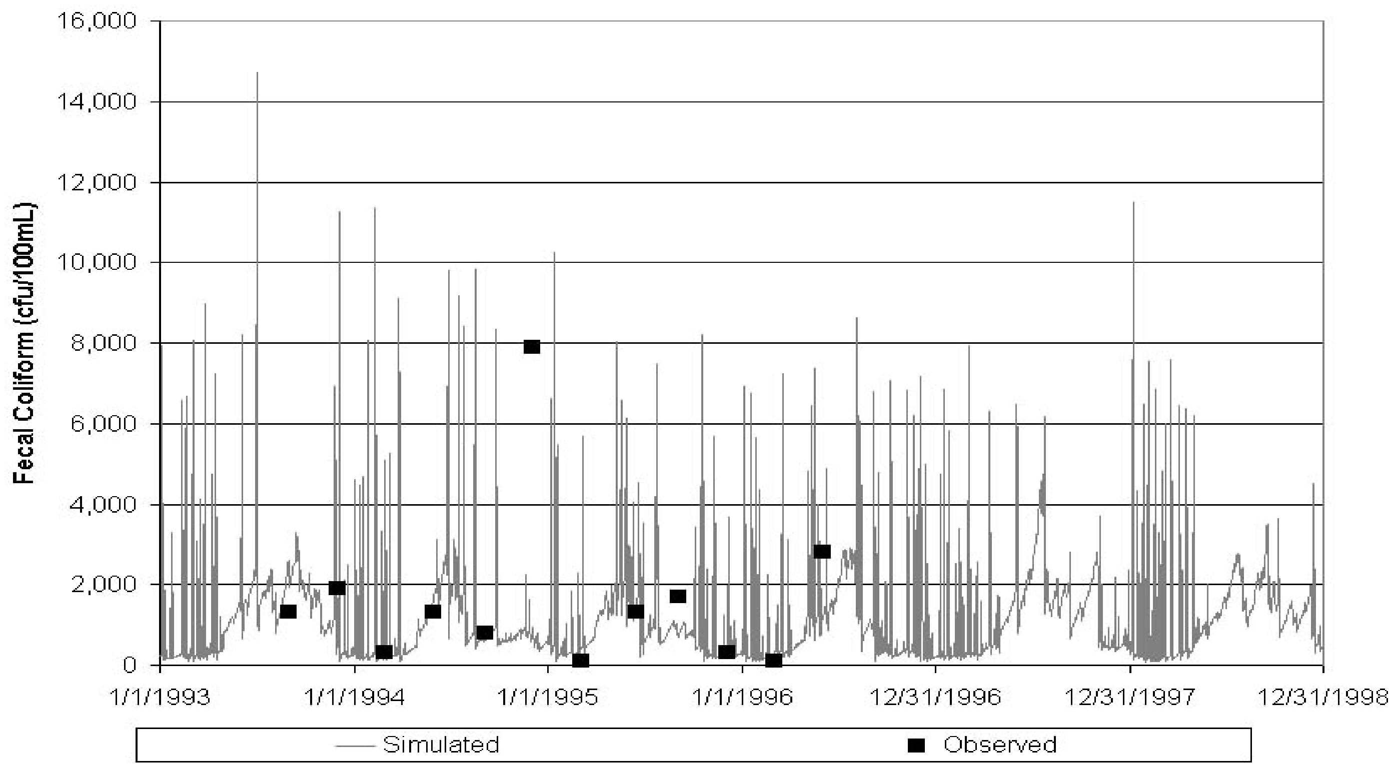

Figure 6.3. Simulated and observed fecal coliform concentrations for Machine Creek DEQ station 4AMCR004.60.

6.4 Load Allocations

6.4.1 Background

The objective of a TMDL is to allocate allowable loads among different pollutant sources so that the appropriate control actions can be taken to achieve water quality standards (USEPA, 1991). The objective of the TMDL for Machine Creek was to determine what reductions in fecal coliform loadings from point and nonpoint sources are required to meet state water quality standards. Machine Creek watershed is part of the uplands of the BOR basin and does not receive flow from any other watersheds. In developing the TMDL plan, water quality was simulated at three points within the impaired segment and the final TMDL was developed for the stream reach that was the most restrictive (required the greatest reductions in loadings to meet the water quality standard). For the Machine Creek watershed, the most restrictive stream reach was located between the confluence of Skinnels Creek with Machine Creek and the confluence of Machine Creek and the Little Otter River. Since Machine Creek is listed as impaired throughout its entire length, all subwatersheds in the Machine Creek HU contribute to the impairment. Load reductions were applied uniformly across the entire watershed.

The state water quality standard for fecal coliform used in the development of the TMDL is the 30-day geometric mean standard of 200 cfu/100mL. The TMDL considers all sources contributing fecal coliform to Machine Creek. The sources can be separated into nonpoint and point (or direct) sources. The incorporation of the different sources into the TMDL are defined in the following equation:

$$TMDL = W\ L\ A + L\ A + MOS \qquad [6.1]$$

where,

WLA	=	waste load allocation (point source contributions);
LA	=	load allocation (nonpoint source contributions); and
MOS	=	Margin of safety.

A MOS is included to account for uncertainty in the TMDL development process. There are several ways that the MOS can be incorporated into the TMDL (USEPA, 1991). For the Machine Creek TMDL, a margin of safety of 5% (i.e. MOS = 10 cfu/100mL) was used. By subtracting the MOS from the TMDL standard of 200 cfu/100mL, the goal of the TMDL allocation was that the combined point source (WLA) and nonpoint source (LA) loads be below the target fecal coliform concentration (30-day geometric mean) of 190 cfu/100mL.

The time period selected for the load allocation study was January 1, 1993 to December 31, 1998, the same as that used for the model calibration. This period incorporates a wide range of hydrologic events including both low and high flow conditions.

6.4.2 Calibration Period and Existing Conditions

The simulation of existing conditions provides the baseline for evaluating reductions required for the TMDL allocation. The calibrated hydrology and water quality parameter sets along with the best estimate of fecal coliform loads in the watershed were used to simulate daily fecal coliform concentrations for the selected allocation study period of Jan 1, 1993 to Dec 31, 1998. Since there is no data available reflecting the change in animal numbers from the calibration period data (1993-1998) to the present (2000) in Machine Creek, the fecal coliform loads and model parameters representing "existing conditions" were the same as the calibration period data. ************

Analysis of the simulation results for the calibration data (Table 6.18) show that fecal coliform loading from direct deposition by cattle is responsible for an average of about 59% of the mean daily fecal coliform concentration in Machine Creek. Loads from PLS on average contribute about 30% of the mean daily fecal coliform concentration, while direct deposition from wildlife accounts for about 10%. The other sources, interflow and groundwater together contribute less than 1% of the mean daily concentration. Simulated 30-day mean fecal coliform concentrations in Machine Creek due to existing Machine Creek loads are shown in Figure 6.4 along with the geometric mean TMDL goal. Simulated concentrations are generally above the geometric mean goal.

Table 6.15. Relative contributions of different fecal coliform sources to the overall mean fecal coliform concentration for the existing and calibration period conditions.

Fecal Coliform Source	Mean Daily Fecal Coliform Concentration Attributable to Source, (cfu/100mL)	Relative Contribution by Source %
Baseline - All Sources	1,260.0	100.0%
Direct Deposit from Cattle Only	742.0	58.9%
Direct Deposit from Wildlife Only	130.0	10.3%
Straight Pipe Discharge Only	0.0	0.0%
Loads from PLS Only	384.0	30.5%
Loads from ILS Only	0.0	0.0%
Contribution from Interflow and Groundwater	4.0	0.3%

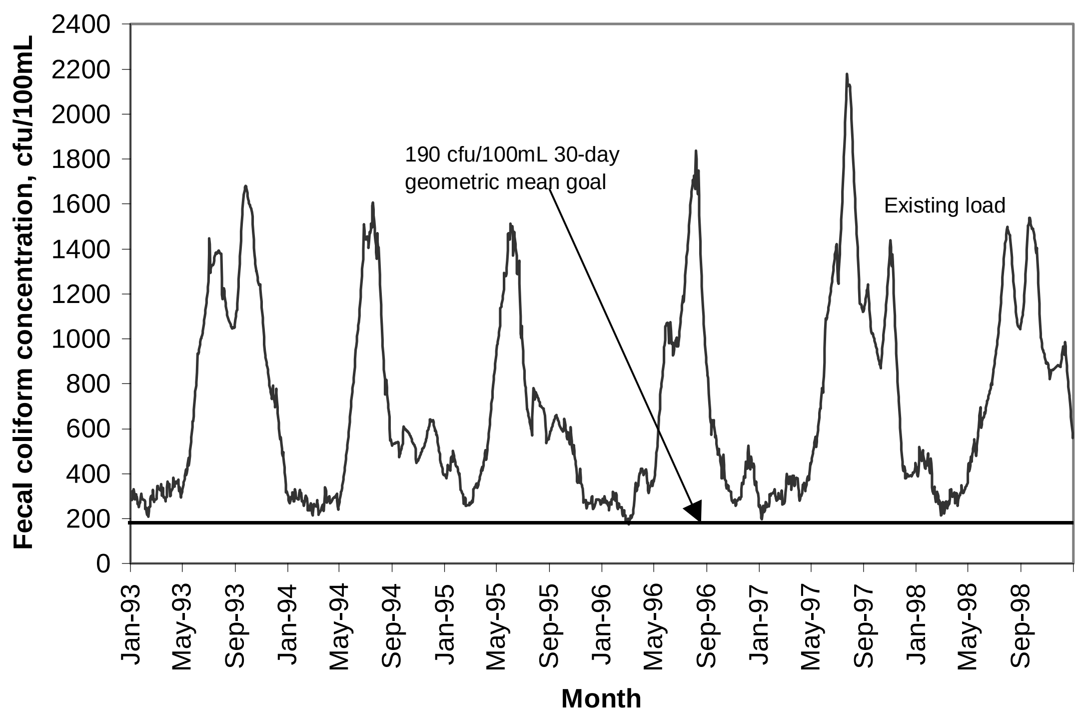

Figure 6.4. Simulated 30-day mean fecal coliform concentrations in Machine Creek at the watershed outlet due to existing loads.

Direct deposits by cattle are a critical source, especially during the summer, when increased time spent in streams corresponds with the decreased dilution associated with low stream flow. In summer months, It is estimated that cattle with access to streams spend two hours per day in water (Table 2.8). Hence, of the 838 cattle on pastures with stream access, an equivalent of 70 cattle spend the entire day in the stream. With the estimate that 30% of the feces of these cattle is deposited directly to the streams, the waste equivalent of 21 cattle is deposited directly in the streams. This represents approximately 2.5% of the manure load of cattle in pastures with stream access. The fraction of manure directly deposited in the stream at other times of the year is lower, but can still contribute to water quality standard exceedances during low-flow periods.

6.4.3 Allocation Scenarios

Several allocation scenarios were evaluated to meet the 30-day geometric mean TMDL goal of 190 cfu/100mL (Table 6.16). Scenarios 8 and 9 meet the TMDL allocation requirement of no violations of the 190 cfu/100mL 30-day geometric mean goal (Table 6.16). Scenario 8 was selected for the TMDL allocation plan. There were no direct pipes in Machine Creek watershed, and therefore, no reductions were required from direct pipes. The concentration of fecal coliform in the impaired stream segment was largely controlled by direct deposition from cattle. When the reduction in direct deposition from cattle was changed from 90% (scenario 2) to 99% (scenario 4), the percent exceedances of the 190 cfu/100mL goal decreased from 24% to 2.5% (Table 6.16). The need for reductions in fecal coliform loads from the land surface is evident from the results of scenario 5 (Table 6.16) that indicates large reductions from the direct sources are needed to meet the standard. The selected scenario for the Machine Creek TMDL allocation plan was scenario 8, which required a 65% reduction in direct wildlife deposits, a 100% reduction in direct deposits by cattle, and a 60% reduction in NPS loadings from agricultural land segments (cropland and pasture).

Table 6.16. Fecal coliform TMDL allocation scenarios for Machine Creek.

Scenario Number	Percent reduction in loading from existing condition[1]				Percentage of days with 30-day GM > 190 cfu/100mL
	Direct wildlife deposits	Direct cattle deposits	NPS from Ag land segments	Direct pipes	
1	0	0	0	0	99.7%
2	60	90	0	0	24.2%
3	60	95	0	0	10.2%
4	60	99	0	0	2.5%
5	60	100	0	0	1.6%
6	60	100	50	0	0.2%
7	60	100	60	0	0.1%
8	**65**	**100**	**60**	**0**	**0.0%**
9	70	100	50	0	0.0%

Bold indicates the scenario selected

Table 6.17 shows the loads from nonpoint sources for all land uses and the results of the 60% reduction called for by the TMDL allocation plan (scenario 8 in Table 6.16). The reductions in direct NPS loads required by the TMDL allocation plan are shown in Table 6.18. The graph of 30-day geometric mean fecal coliform concentrations for existing conditions and for the TMDL allocation plan (Figure 6.5) shows that simulated concentrations do not exceed the geometric mean goal of 190 cfu/100mL during the allocation period.

Table 6.17. Annual NPS loads to Machine Creek for existing conditions and the TMDL allocation plan (scenario 8).

Pervious Land Segment Category	Existing conditions		Allocation Scenario	
	Existing load ($\times 10^{12}$ cfu)	Percent of total load to stream from NPS	TMDL NPS allocation load ($\times 10^{12}$ cfu)	Percent reduction from existing load
Commercial/Industrial	<0.01	< 0.1	<0.01	0
Cropland	0.13	< 0.1	0.05	60
Forest	1.49	0.2	1.49	0
High Density Residential	0.01	< 0.1	0.01	0
Pasture	996.32	99.5	398.53	60
Rural Residential	3.30	0.3	3.30	0
Total	**1,001.24**	**100.0**	**403.38**	**59.7**

Table 6.18. Annual direct NPS loads to Machine Creek for existing conditions and for the TMDL allocation plan (scenario 8).

Source	Existing Conditions		Allocation Scenario	
	Fecal coliform load ($\times 10^{12}$ cfu/year)	Percent of total load to stream from direct NPS	NPS allocation load ($\times 10^{12}$ cfu/year)	Percent reduction
Cattle in stream	126.6	79.86	0.0	100.0
Wildlife in stream	31.9	20.14	11.2	65.0
Straight pipes	0.0	0.0	0.0	0.0
Total	**158.5**	**100**	**11.2**	**92.9**

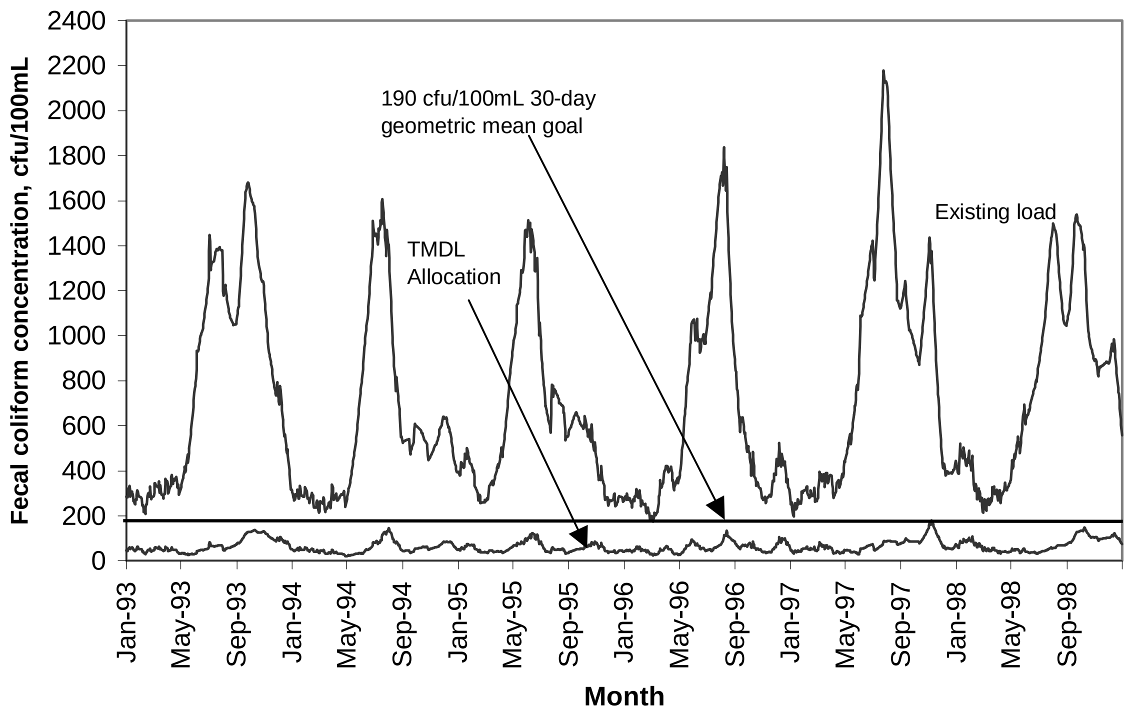

Figure 6.5. Machine Creek TMDL allocation plan, 190 cfu/100mL 30-day geometric mean goal, and existing conditions.

6.4.4 Summary of TMDL Allocation

A TMDL for fecal coliform has been developed for Machine Creek. The TMDL addresses the following issues.

1 The TMDL meets the water quality standard of no exceedances of the 30-day geometric mean fecal coliform concentration of 200 cfu/100 mL..

2 A MOS of 5% was incorporated in the development of the TMDL plan.

3 The TMDL accounts for fecal coliform from human, domestic/agricultural animals, and wildlife sources.

4 Both high and low-flow stream conditions were considered in developing the TMDL. In the Machine Creek watershed, low flow conditions were found to be the environmental condition most likely to cause a violation of the 30-day geometric mean.

5 Both the flow regime and fecal coliform loadings are seasonal, with higher loadings and in-stream concentrations during the summer than in the winter. The TMDL accounts for these seasonal effects.

6 A TMDL allocation plan to meet the 30-day geometric mean water quality goal of 190 cfu/100mL requires: a 100% reduction in direct deposits of cattle manure to streams, a 65% reduction in direct deposits by wildlife to streams, and a 60% reduction in NPS loadings from agricultural land segments (cropland and pasture). The annual fecal coliform loads for the selected TMDL allocation scenario are summarized in Table 6.19.

Table 6.19. Annual fecal coliform loadings (cfu/year) for the Machine Creek watershed (L26a) fecal coliform TMDL.

Subwatershed	Point Source Loads	Nonpoint Source Loads	Margin of Safety[a]	TMDL Annual Load
Machine Creek	$<0.1 \times 10^{12}$	414.6×10^{12}	21.8×10^{12}	436.4×10^{12}

[a] Five percent of TMDL

7 TMDL FOR THE LITTLE OTTER RIVER WATERSHED

7.1 Watershed Characterization

7.1.1 Water Resources

The Little Otter River watershed (L26b) has 36.1 miles of primary and secondary streams. In addition to the Little Otter River and its South Branch, the stream network in the watershed includes Johns Creek and Poorhouse Creek, both of which drain into the Little Otter River (Figure 7.1). Near the watershed outlet, Machine Creek drains into the Little Otter River. At the outlet of the watershed, the Little Otter River drains into the BOR. The headwaters of the watershed are located in the Blue Ridge physiographic province, where the potential for groundwater pollution is low (VWCB, 1985). The remainder of the watershed is located in the Piedmont physiographic province, with a moderate to low groundwater pollution potential (VWCB, 1985). Depth to the seasonal high water table in the watershed is generally greater than 6 ft below the mineral soil surface (SCS, 1989).

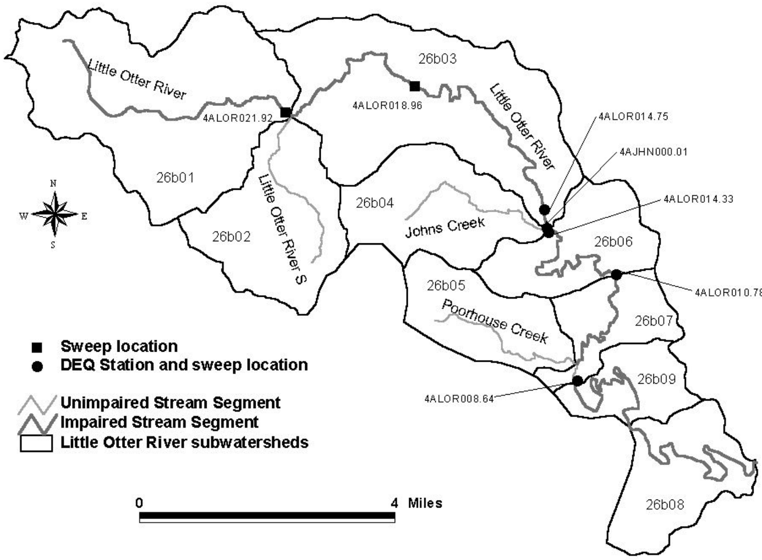

Figure 7.1. Little Otter River (L26b) subwatersheds, stream network, locations of VADEQ water quality monitoring sites and sweep sites for flow and water quality monitoring

7.1.2 Soils

The two soil associations found in the watershed are Hayesville-Edneytown-Braddock and Cecil-Madison. The Hayesville-Edneytown-Braddock soils are found mainly in the headwaters while the Cecil-Madison soils are found in the remaining area of the watershed. Detailed descriptions of these soil associations are given in Section 2.5.2.

7.1.3 Land use

The Little Otter River watershed (L26b) was divided into nine subwatersheds to spatially analyze waste or fecal coliform distribution within the watershed (Figure 7.1). Land use distribution in the subwatersheds and the entire Little Otter River watershed is presented in Table 7.1. Forest and pasture are primary land use categories, occupying 42.2 and 35.5% of the total acreage, respectively.

Table 7.1. Land use distribution (acres) among the subwatersheds of the Little Otter River watershed (L26b)

Land use	Subwatershed									Total[a]	
	26b01	26b02	26b03	26b04	26b05	26b06	26b07	26b08	26b09	Acres	%
Commercial/ industrial	31	62	21	58	21	22	18	2	0	235	0.9
Cropland	189	22	14	30	122	0	21	151	7	556	2.1
Forest	2,126	1,031	2,100	1,143	862	1,069	766	1,271	622	10,990	42.2
High density residential	301	844	897	817	96	85	71	16	3	3,130	12.0
Pasture	3,089	734	2,173	245	768	709	420	637	477	9,252	35.5
Rural residential	254	291	647	289	69	101	91	63	98	1,903	7.3
Total[a]	**5,990**	**2,984**	**5,852**	**2,582**	**1,938**	**1,986**	**1,387**	**2,140**	**1,207**	**26,066**	**100.0**

[a] Component acreages may not add up due to round-off error.

7.1.4 Flow and Water Quality Data

Historic data

The VADEQ collected water quality samples at four monitoring stations on the Little Otter River (Figure 7.1). However, no concomitant flow data were collected at any monitoring site. The water quality samples were analyzed for fecal coliform using the MFT with a maximum concentration cap of 8,000 cfu/100 mL. The period of data collection, number of samples collected, and the mean, maximum, and minimum fecal coliform concentrations for each VADEQ monitoring station on the Little Otter River are presented in Table 7.2.

Table 7.2. Period of data collection, number of samples, and mean, maximum, and minimum fecal coliform concentrations for each VADEQ monitoring station in the Little Otter River watershed (L26b)

VADEQ monitoring station	Period of record	Number of samples	Fecal coliform concentration (cfu/100 mL)		
			Mean	Maximum	Minimum
4ALOR014.75	11/74-12/98	165	839	8,000[a]	100
4ALOR014.33	9/88-6/93	27	975	8,000[a]	100
4ALOR010.78	1/72-6/96	115	887	8,000[a]	100
4ALOR008.64	7/96-12/98	29	1,317	8,000[a]	100

[a] Membrane Filtration Technique Cap

Monitoring station 4ALOR014.75 is located immediately upstream of the City of Bedford STP, while 4ALOR014.33 is located immediately downstream of the City of Bedford STP. The monitoring stations 4ALOR010.78 and 4ALOR008.64 are located progressively downstream of 4ALOR014.33. Since concomitant flow data were not available and the periods of record are not the same for 4ALOR014.75 and 4ALOR014.33, it is unclear if the higher mean fecal coliform concentration at 4ALOR014.33 (Table 7.2) was due to wastewater overflows from the City of Bedford STP. It was noted that the City of Bedford STP is not permitted for combined sewage overflows (VPDES Permit No. VA0022390). The maximum fecal coliform concentrations reported in Table 7.2 could have been higher since an MFT concentration cap of 8,000 cfu/100 mL had been used in sample analysis. Time series data of fecal coliform concentration observed at the most upstream (4ALOR014.75) and downstream (4ALOR008.64) VADEQ monitoring stations are compared for the same period of record in Figure 7.2.

The percentage of exceedances of the instantaneous standard of 1,000 cfu/100 mL was slightly higher (27.6%) at 4ALOR008.64, the downstream monitoring station than at 4ALOR014.75 where 24.1% of the samples exceeded the instantaneous standard. Seasonal fecal coliform trends could not be compared between the two monitoring stations due to the short period of record for station 4ALOR008.64. Further, given the lack of flow data, no inferences could be made regarding the impact of flow on fecal coliform concentration.

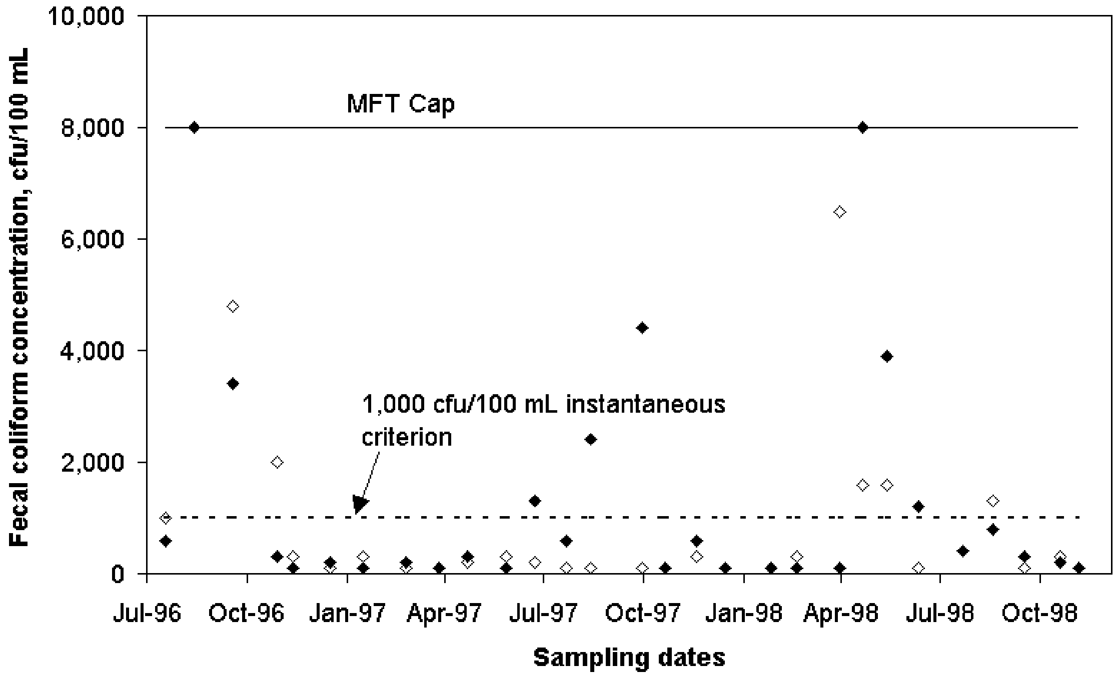

Figure 7.2. Time series of fecal coliform concentration observed in VADEQ monitoring stations 4ALOR014.75 (◊) and 4ALOR008.64 (♦) on the Little Otter River

Water quality sweep and flow measurement

The VADEQ and Virginia Tech conducted a water quality and flow-monitoring sweep on March 20-22, 2000. The purpose of the sweep was to assess water quality conditions at various stations within the Little Otter River watershed. The following factors were considered in selecting the monitoring sites for conducting the sweep.

- Water quality at the monitoring site should be representative of the impact of Land use practices immediately upstream of the site;
- the monitoring site should be in close proximity to a road or bridge so that the site would be located on public land with easy access; and
- the monitoring site should be located at the outlet of the subwatershed.

Seven monitoring sites were selected that met the criteria. The sites are described in Table 7.3 and their locations are indicated in Figure 7.1.

Table 7.3. Location and description of sampling sites for instantaneous water quality and flow assessment

ID	Stream	Location
4ALOR021.92	Little Otter River	Bridge on Rt. 838 near intersection of Rt. 838 and Rt. 43
4ALOR018.96	Little Otter River	Bridge on Rt. 122 northeast of Bedford and north of intersection of Rt. 122 and US Rt. 221
4ALOR014.75	Little Otter River	Bridge on Rt. 718 east of Bedford
4ALOR014.33	Little Otter River	Immediately upstream from the confluence of Johns Creek and Little Otter River
4ALOR010.78	Little Otter River	Bridge on US Rt. 460 east of Bedford, west of intersection of US Rt. 460 and Rt. 715
4ALOR008.64	Little Otter River	Bridge on Rt. 784 near intersection of Rt. 784 and Rt. 714
4AJHN000.01	Johns Creek	Immediately upstream from the confluence of Johns Creek and Little Otter River

At each site, staff from VADEQ collected two water samples, one from below the stream surface and another at the bottom of the stream (after disturbing the streambed). Samples were stored on ice and were analyzed for fecal coliform within 24 hours using the MPN method by the DCLS in Richmond. The MPN method used a maximum detection limit of 160,000 cfu/100 mL. Flow rate was calculated by multiplying the flow velocity (measured with a current meter) with the measured channel cross-sectional area. The results of the sweep are presented in Table 7.4.

In the seven days preceding the sweep, a total of 1.67 inches of precipitation was recorded at Lynchburg Regional Airport with 1.17 inches of the amount recorded in the preceding 48 hours. Fecal coliform concentrations in the stream surface and bottom samples exceeded the instantaneous standard at all sites. Fecal coliform concentrations in both stream surface and bottom samples were lower closer to the watershed outlet (4ALOR008.64) and in Johns Creek (4AJHN000.01) than at the other monitoring stations located on the Little Otter River (Table 7.3). Since the fecal coliform concentrations in both the surface and bottom samples at 4ALOR021.92 through 4ALOR010.78 were at the 160,000-cap level (Table 7.3), actual fecal coliform concentrations could have been higher. Equal or higher fecal coliform concentrations in the stream bottom samples than at the stream surface indicated that fecal coliform accumulation in the stream sediment was significant.

Table 7.4. Results of the instantaneous fecal coliform and flow assessment

ID	Stream	Flow (cfs)	Fecal coliform counts (cfu/100 mL)	
			Stream surface[a]	Stream bottom[b]
4ALOR021.92	Little Otter River	13.06	160,000[c]	160,000[c]
4ALOR018.96	Little Otter River	40.70	160,000[c]	160,000[c]
4ALOR014.75	Little Otter River	60.30	160,000[c]	160,000[c]
4ALOR014.33	Little Otter River	70.20	160,000[c]	160,000[c]
4ALOR010.78	Little Otter River	84.90	160,000[c]	160,000[c]
4ALOR008.64	Little Otter River	104.00	28,000	35,000
4AJHN000.01	Johns Creek	8.247	7,900	17,000

[a] Sample was obtained from just below the stream surface.

[b] Stream bottom was stirred prior to sample collection.

[c] Upper limit of detection

7.2 Source Assessment of Fecal Coliform

Procedures used in quantifying fecal coliform sources are discussed in Section 2.6. Specific information for the Little Otter River watershed is presented in the following sections.

7.2.1 Point Source

There are four permitted point sources in the Little Otter River watershed (Table 7.5). All four sources are required to chlorinate, and they are permitted to discharge fecal coliform at a rate of 200 cfu / 100 mL.

Table 7.5. List of permitted point sources in the Little Otter River watershed (L26b)

Permitted point source	VPDES Permit No.
Thaxton Elementary School	VA00220869
Liberty High School	VA0020796
City of Bedford STP	VA0022390
Echols Creek, Inc. Dillon's Trailer Park	VA0087840

7.2.2 Nonpoint Source

Nonpoint sources of fecal coliform in the Little Otter River watershed include humans, pets, livestock, and wildlife. Fecal coliform from these sources that directly deposited in the stream are characterized as a direct nonpoint source while fecal coliform applied or deposited on the land is termed as nonpoint source.

Humans

Based on an average household size of 2.5 persons, the Little Otter River watershed has an estimated total human population of 10,910. Distribution of human populations among the subwatersheds is shown in Table 7.6.

Table 7.6. Distribution of human and pet populations in the Little Otter River watershed

Subwatershed	Human population	Pet population
26b01	1,197	479
26b02	3,450	1,380
26b03	2,505	1,002
26b04	2,405	962
26b05	582	233
26b06	338	135
26b07	195	78
26b08	98	39
26b09	140	56
Total	**10,910**	**4,364**

Failing septic systems

Based on an average household size of 2.5 persons and a fecal coliform production of 1.95 $\times$ 10^9 cfu/day, a typical failing septic system contributes 4.88 $\times$ 10^9 cfu/day to the rural residential Land use. The numbers of failing septic systems in the subwatersheds of Little Otter River are shown in Table 7.7.

Biosolids

During 1990 - 1999, pastures in subwatershed 26b01 (Figure 7.1) received biosolids. Based on information provided by VADEQ and VDH, biosolids applications to pastures in subwatershed 26b01 during that period are shown in Table 7.8; there were no biosolids applications to cropland in the Little Otter River watershed. As described in Chapter 3, the 1993 - 1998 period was considered in evaluating fecal coliform loading under existing conditions.

Table 7.7. Estimated number of unsewered households by age, number of failing septic systems, and straight pipes in the Little Otter River watershed (L26b)

Subwatershed	Unsewered houses by age (no.)				Failing septic systems (no.)	Straight pipes (no.)
	Pre-1967	1967-1985	Post-1985	Total		
26b01	210	119	62	391	110	1
26b02	37	11	10	58	17	0
26b03	123	207	114	444	94	0
26b04	32	51	31	114	24	0
26b05	32	25	52	109	19	0
26b06	67	58	10	135	39	0
26b07	21	23	34	78	14	0
26b08	23	8	8	39	11	0
26b09	17	13	26	56	10	0
Total	**562**	**515**	**347**	**1,424**	**338**	**1**

Table 7.8. Biosolids application to pasture in subwatershed 26b01 in the Little Otter River watershed (L26b)

Month	Pasture area (acres)	Biosolids application rate (dry tons/acre)	Fecal coliform application rate ($\times 10^9$ cfu/acre)
August 1995	61	5.2	.47
September 1995	51	8.5	.778

Straight pipes

A household with a straight pipe contributes 4.88×10^9 cfu/day (household size multiplied by daily fecal coliform production) directly into the stream. The numbers of straight pipes in the subwatersheds of Little Otter River are given in Table 7.7.

Pets

Based on the assumption of one pet per household, the number of pets in each subwatershed of the Little Otter River was calculated (Table 7.6). Fecal coliform loading from pets is distributed between the rural residential and high-density residential land uses based on the number of pets in each land use. Pet loading is applied to each of the two land uses by multiplying the number of pets by the fecal coliform produced by a pet (450×10^6 cfu/day) in that land use.

Livestock

Beef cattle

Beef cattle in the Little Otter River watershed were distributed among the subwatersheds based on their pasture acreages. The number of beef cattle in each subwatershed is shown in Table 7.9.

Table 7.9. Distribution of beef cattle, dairy cattle, and horses among the subwatersheds in the Little Otter River watershed (L26b)

Subwater-shed	Beef	Dairy[a]		Horses
		Pre-1996	Current	
26b01	567	167	155	87
26b02	135	0	0	21
26b03	399	0	0	61
26b04	45	0	0	7
26b05	140	0	0	21
26b06	131	0	0	20
26b07	76	0	0	12
26b08	117	482	450	18
26b09	87	0	0	13
Total	**1,697**	**649**	**605**	**260**

[a] Includes milk cows, dry cows, and heifers

Dairy cattle

Distribution of dairy cattle among the subwatersheds is given in Table 7.9. As discussed in Section 2.6, the pre-1996 dairy numbers are based on 1987 and 1992 Agricultural Census and were used for the calibration period. The existing dairy numbers were used for simulating the allocation scenarios.

Horses

Horses were distributed among the subwatersheds based on their pasture acreages. Distribution of horses among the subwatersheds is given in Table 7.9.

Direct manure deposition in streams

Manure deposition in streams is affected by the number of beef and dairy cattle in the watershed as well as the percentage of pastures with stream access. The percentage of pasture with stream access in each subwatershed (Table 7.10) of the Little Otter River was calculated using the procedure given in Section 2.6.

While milk cows are confined part of the year, dry cows, heifers, and beef cattle are not confined. When not confined, milk cows as well as other cattle deposit their waste on pasture and into streams. Monthly distribution of cattle in confinement, on pasture, and in streams in the Little Otter River watershed (Table 7.10) were calculated based on the confinement schedule for milk cows (Table 2.8), time spent by cattle in the stream (Table 2.8), and percent of pasture with stream access (Table 7.10). Cattle in the stream (Table 7.11) represent the number of cattle defecating in the stream, assuming that 30% of the cattle in and around the stream defecate in the stream.

Table 7.10. Percentage of pasture with stream access in the subwatersheds of the Little Otter River watershed (L26b)

Subwater -shed	Percent of pasture with stream access
26b01	73
26b02	65
26b03	42
26b04	70
26b05	42
26b06	40
26b07	35
26b08	42
26b09	20
Average	**48**

Fecal coliform deposition in the stream by a type of cattle (e.g., milk cow) was calculated by multiplying the number of cattle in the stream by the fecal coliform production (Table 2.4). Total fecal coliform deposition was calculated by adding the fecal coliform production by the different types of cattle defecating in the stream. Annual fecal coliform loading to the streams in the subwatersheds of the Little Otter River watershed by dairy and beef cattle are given in Table 7.12.

Table 7.11. Monthly distribution of dairy and beef cattle between pasture and stream in the Little Otter River watershed (L26b)

Month	Dairy[a]			Beef		Total	
	Confined[b]	Pasture	Stream	Pasture	Stream	Dairy[a]	Beef
January	152 (141)	496 (463)	1 (1)	1,693	4	649 (605)	1,697
February	152 (141)	496 (463)	1 (1)	1,693	4	649 (605)	1,697
March	88 (82)	559 (521)	2 (2)	1,693	4	649 (605)	1,697
April	76 (71)	571 (532)	2 (2)	1,690	7	649 (605)	1,697
May	76 (71)	570 (531)	3 (3)	1,688	9	649 (605)	1,697
June	76 (71)	567 (529)	6 (5)	1,678	19	649 (605)	1,697
July	76 (71)	567 (529)	6 (5)	1,678	19	649 (605)	1,697
August	76 (71)	567 (529)	6 (5)	1,678	19	649 (605)	1,697
September	76 (71)	570 (531)	3 (3)	1,688	9	649 (605)	1,697
October	76 (71)	571 (532)	2 (2)	1,690	7	649 (605)	1,697
November	88 (82)	559 (521)	2 (2)	1,693	4	649 (605)	1,697
December	152 (141)	496 (463)	1 (1)	1,693	4	649 (605)	1,697

[a] Figures outside the parentheses represent pre-1996 numbers while the figures inside the parentheses represent current numbers.

[b] Only milk cows are confined.

Table 7.12. Annual fecal coliform loadings to stream and pasture by dairy and beef cattle in the subwatersheds of the Little Otter River watershed (L26b)

Subwater-shed	Stream ($\times 10^{12}$ cfu/year)		Pasture ($\times 10^{12}$ cfu/year)	
	Pre-1996	**Current**	**Pre-1996**	**Current**
26b01	5.9	5.8	7,662	7,599
26b02	11.2	11.2	1,618	1,618
26b03	21.0	21.0	4,791	4,791
26b04	4.0	4.0	539	539
26b05	7.4	7.4	1,687	1,687
26b06	6.6	6.6	1,568	1,568
26b07	3.4	3.4	920	920
26b08	17.2	1.7	3,857	372
26b09	2.2	2.2	1,051	1,051
Total	**78.9**	**63.3**	**23,693**	**20,145**

Direct manure deposition on pastures

Based on stream access by subwatershed (Table 7.10), the number of dairy and beef cattle depositing fecal coliform on pasture are presented in Table 7.11. Total fecal coliform deposition on pasture was calculated by adding the fecal coliform production by dairy and beef cattle defecating on the pasture. Annual fecal coliform loadings on the pastures in the subwatersheds of the Little Otter River by the dairy and beef cattle are given in Table 7.12.

Land application of dairy manure

A typical milk cow weighs 1,400 lb and produces 17 gallons of liquid manure per day (ASAE, 1998). Hence, annual dairy manure production in confinement was estimated at 0.60 million gallons; current production was estimated to be 0.56 million gallons/year. There are two dairy operations, one in subwatershed 26b01 and the other in 26b08. It was assumed that all dairy manure produced in confinement in a subwatershed was applied to cropland and pasture at 8,000 and 4,000 gallons/acre-year, respectively, within the subwatershed. Based on the pre-1996 numbers, in subwatershed 26b01, it was estimated that 7.9 and 0.4% of cropland and pasture, respectively, received dairy manure as per the application schedule given in Table 2.10. Currently, in subwatershed 26b01, 7.3 and 0.4% of cropland and pasture, respectively, receive dairy manure. In subwatershed 26b08, 24.7 and 5.0% of cropland and pasture, respectively, received dairy manure during the pre-1996 period. Currently, it is estimated that 2.3% and 0.5% of cropland and pasture in subwatershed 26b08, respectively, receive dairy manure. Depending on the storage capacity (and hence, length of storage), fecal coliform in stored manure is subject to die-off (discussion on storage capacity for dairy manure is given in Section 2.6).

After accounting for die-off during storage (Section 3.4), during the pre-1996 period, fecal coliform loadings from dairy manure to cropland and pasture in subwatershed 26b01 were estimated to be 1.2×10^{12} and 0.6×10^{12} cfu/year, respectively. Under current conditions, cropland and pasture in subwatershed 26b01 receive 1.1×10^{12} and 0.6×10^{12} cfu/year, respectively, from dairy manure. During the pre-1996 period, fecal coliform loadings from dairy manure to cropland and pasture in subwatershed 26b08 were estimated to be 3.0×10^{12} and 1.0×10^{12} cfu/year, respectively. Under current conditions, cropland and pasture in subwatershed 26b08 receive 0.3×10^{12} and 0.1×10^{12} cfu/year, respectively, from dairy manure.

Wildlife

Based on the animal density (animals/acre-habitat) and acreage of habitat (Section 2.6), the wildlife species were distributed among the subwatersheds of the Little Otter River watershed (Table 7.13). Depending on the wildlife species, an animal deposits part of its waste loading directly into the stream (Table 2.11), while the remainder is deposited on land. The waste that was deposited on land was distributed among the different land use types that constituted the wildlife species habitat based on their percentages of the total habitat.

Annual distribution of fecal coliform loading from wildlife between the stream and different Land use types is given in Table 7.14.

Table 7.13. Distribution of wildlife among the different subwatersheds of the Little Otter River watershed (L26b)

Wildlife species	Subwatersheds									Total
	26b01	26b02	26b03	26b04	26b05	26b06	26b07	26b08	26b09	
Deer	282	140	275	121	91	93	65	101	57	1,225
Raccoon	31	51	73	30	29	29	25	39	30	337
Muskrat	146	244	365	146	140	168	135	221	182	1,747
Beaver	24	14	36	15	14	17	13	22	18	173
Goose	24	12	23	10	8	8	6	9	5	105
Duck	11	5	11	5	4	4	3	4	2	49
Mallard	12	6	12	5	4	4	3	4	2	52
Wild Turkey	10	21	21	11	9	11	8	13	6	110

7.2.3 Summary: Contribution from All Sources

Based on the inventory of sources discussed in Sections 7.2.2.1 through 7.2.2.4, contribution of the different nonpoint sources to direct annual fecal coliform loading to the streams for both the pre-1996 and current conditions is given in Table 7.15. Distribution of annual fecal coliform loading from nonpoint sources among the different Land use categories for both the pre-1996 and current conditions are also given in Table 7.15.

Table 7.14. Annual distribution of fecal coliform from wildlife among the different Land use types and streams in the subwatersheds of the Little Otter River watershed (L26b)

Subwater -shed	Annual fecal coliform loading ($\times 10^9$ cfu/year)						Total
	Stream	Cropland	Forest	High Density Residential	Pasture	Rural Residential	
26b01	21.9	3.1	55.5	19.1	61.4	19.9	**180.9**
26b02	13.2	1.6	29.1	2.4	50.0	2.3	**98.6**
26b03	24.9	0.2	88.1	14.5	49.8	11.4	**188.9**
26b04	10.7	0.5	37.3	14.5	10.3	9.1	**82.4**
26b05	8.9	2.6	28.8	1.6	21.0	2.2	**65.1**
26b06	9.2	0.0	40.9	1.4	13.4	1.7	**66.6**
26b07	7.0	0.4	28.1	1.2	10.7	1.5	**48.9**
26b08	10.2	2.6	44.1	0.3	14.7	1.0	**72.9**
26b09	6.2	0.6	22.1	0.1	11.0	2.0	**42.0**
Total	**112.2**	**11.6**	**374**	**55.1**	**242.3**	**51.1**	**846.3**

Table 7.15. Annual fecal coliform loadings to the stream and the various land use categories in the Little Otter River watershed (L26b)

Source	Pre-1996		Current	
	Fecal coliform loading ($\times 10^{12}$ cfu/year)	Percent of total loading	Fecal coliform loading ($\times 10^{12}$ cfu/year)	Percent of total loading
Direct loading to streams				
Cattle in stream	173.8	0.63	130.4	0.59
Wildlife in stream	41.0	0.15	41.0	0.19
Straight pipes	1.8	<0.01	1.8	<0.01
Loading to land surfaces				
Commercial/industrial	0.88	<0.01	0.88	<0.01
Cropland	8.41	0.03	5.60	0.02
Forest	136.51	0.49	136.51	0.62
High density residential	502.99	1.81	502.99	2.30
Pasture	26,022.84	93.89	20,235.92	92.47
Rural residential	829.02	2.99	829.02	3.80
Total	**27,717.26**	**100.0**	**21,884.12**	**100.0**

From Table 7.15, it is clear that nonpoint source loadings to the land surface are 100 times larger than direct nonpoint source loadings to the streams, with pastures receiving more than 93% of the total fecal coliform load. It could be prematurely assumed that most of the fecal coliform loading in streams originates from upland sources, primarily, from pastures. However, other factors such die off and runoff rates also impact the amount of fecal coliform from upland areas that reaches the streams.

7.3 Modeling Process

7.3.1 Introduction

The 26,065 acre Little Otter River watershed is located in the west central portion of the BOR basin. The two principal land uses are forest and pasture, but there are also significant urban and residential areas due to the City of Bedford. The Little Otter River is listed as impaired from its headwaters to its confluence with BOR. The VADEQ has four monitoring stations (4ALOR014.75, 4ALOR014.33, 4ALOR010.78, and 4ALOR08.64) located along the Little Otter River. Since no monitored flow data was available at these stations or at any other point within the Little Otter River watershed, the hydrology parameter set developed during the BOR hydrology calibration was used for the Little Otter

River. The water quality parameters were calibrated to give the best fit to the observed data at the four VADEQ monitoring stations.

7.3.2 Selection of Subwatersheds

The Little Otter River watershed was subdivided into nine subwatersheds and ten reaches (Fig. 7.1) for modeling purposes. The subwatersheds and reaches were delineated based on the stream network, land use patterns and the presence of monitoring stations and point source discharges. There were five permitted point sources within the Little Otter River watershed, but three were not considered significant because they had no reported discharge or because their discharges were insignificant (less than 0.1 cfs). One direct NPS discharge due to direct pipes from on-site wastewater disposal systems was assumed and simulated.

7.3.3 Input Data

The HSPF model requires a wide variety of input data to describe hydrology, water quality, and land use characteristics of the watershed. The different types and sources of input data used to develop the TMDL for the Little Otter River watershed are discussed below.

Climatological Data

Hourly precipitation data were obtained from the NCDC cooperative weather station at Lynchburg Municipal Airport, located approximately 10 miles to the east of the watershed. A complete set of surface meteorological data and hourly precipitation data was available for the Lynchburg station. Detailed descriptions of the weather data and the procedure for converting the raw data into the required data set is described in Appendix B.

Hydrology Model Parameters

The hydrology parameters required by PWATER and IWATER were defined for every land use category for each subwatershed. For each reach, a function table (FTABLE) is required to describe the relationship between water depth, surface area, volume, and discharge (Donigian et al., 1995). These parameters were estimated by surveying representative channel cross-sections in each subwatershed. Hydrology parameters required for the PWATER, IWATER, HYDR, and ADCALC sub-modules are listed in Appendix B.1 of BASINS ver. 2.0 User's Manual (Lahlou et al., 1998). Parameters required as inputs for

PQUAL, IQUAL, and GQUAL are given in Appendix B.1 of BASINS ver. 2.0 User's Manual (Lahlou et al., 1998). Values for the parameters were estimated based on local conditions when possible, otherwise the default parameters provided within HSPF were used. Key HSPF parameters used in the Little Otter River simulations are listed in Table 7.2.

Land use

Virginia DCR identified 24 land uses in the BOR basin. As described in Chapter 2, the 24 land uses were consolidated into six categories based on hydrologic, waste application, and production characteristics (Table 2.2). The land use categories were assigned pervious/impervious percentages, which allowed a land use with both pervious and impervious fractions to be modeled using both the PERLND and IMPLND modules. Land use data were used to select several hydrology and water quality parameters for the simulations.

7.3.4 Model Calibration and Validation

Simulation of the Little Otter River watershed with NPSM was extremely challenging. Simulating ten reaches, nine subwatersheds, two permitted point sources, two combined sewer overflows (CSO), and the Machine Creek inflow stretched NPSM's file and memory limits to their fullest. The CSO from the City of Bedford and the Machine Creek inflows were simulated as hourly point source mutsin file loadings according to procedures recommended in BASINS Technical Note 4 (USEPA, 1999). Time series inputs to represent the inflow to the Little Otter River from Machine Creek were the appropriate output (existing conditions, TMDL allocation plan or Phase 1 implementation plan) from the Machine Creek simulations. Data on the CSO was obtained from monthly discharge monitoring reports supplied by VADEQ. These reports indicated when and where CSO occurred and the estimated CSO volume in millions of gallons. In simulating the CSO, the reported discharge was assumed to occur over a 24-hour period and a fecal coliform concentration of 500,000 cfu/100mL was assumed (Metcalf and Eddy, 1991). The combined sewer overflows were assumed to discharge at two locations: mile point 2.0 in the Little Otter River 06 reach and at the Bedford STP at mile point 3.36 of Johns Creek. Simulation of the existing conditions was simplified somewhat because all of the permitted point sources were simulated as having no fecal coliform load due to chlorination of their effluents. In addition, several permitted point source discharges were not simulated because they were chlorinated and had no reported discharges or their flows were insignificant. For the TMDL allocation scenario and the Phase

1 implementation plans, the permitted point sources with significant flow were simulated as having constant discharges of 200 cfu/100mL (fecal coliform) and whatever the permitted design discharge was. It was assumed that the CSO would be eliminated as part of the TMDL allocation plan, and consequently, CSO were not simulated during the TMDL allocation period.

The water quality component of HSPF was calibrated by comparing the simulated daily fecal coliform values with 161 Little Otter River fecal coliform samples collected by VADEQ between 1989 and 1998 at the four VADEQ monitoring stations. The goodness of the calibration was evaluated visually using graphs of simulated and observed values. The initial water quality parameters selected for the Little Otter River were adequate and parameter adjustment through calibration was not required. Water quality parameters were the same as those used in the Machine and Elk Creek watersheds. The only difference between Sheep Creek and the Little Otter River water quality parameters was the pervious land wash-off factor (WSQOP), which was 1.0 in Sheep Creek and 1.8in/hr in the Little Otter River and all other watersheds except Elk Creek, which was 2.4in/hr. Other HSPF fecal coliform parameters used in model calibration are presented in Table 7.16. As shown in Figures 7.3 to 7.6, the calibrated HSPF water quality parameters fit the observed data for the existing conditions well and the model was judged to be adequately calibrated.

Table 7.16. Input parameters used in HSPF simulations for the Little Otter River.

			RANGE OF VALVES						
PARAMETER	DEFINITION	UNITS	TYPICAL		POSSIBLE		START	FINAL	FUNCTION OF…
PERLIND			MIN	MAX	MIN	MAX		CALIB.	
PWAT-PARM2									
FOREST	Fraction forest cover	none	0.00	0.5	0	0.95	0.0, 1.0	1.0 forest, 0.0 other	Forest cover
LZSN	Lower zone nominal soil moisture storage	inches	3	8	2	15	14.1	4.5-11.3[1]	Soil properties
INFILT	Index to infiltration capacity	in/hr	0.01	0.25	0.001	0.5	0.16	0.054-0.086[1]	Soil and cover conditions
LSUR	Length of overland flow	feet	200	500	100	700	300	300	Topography
SLSUR	Slope of overland flowplane	none	0.01	0.15	0.001	0.3	0.035	0.05	Topography
KVARY	Groundwater recession variable	1/in	0	3	0	5	0	0	Calibrate
AGWRC	Base groundwater recession	none	0.92	0.99	0.85	0.999	0.98	0.97	Calibrate
PWAT-PARM3									
PETMAX	Temp below which ET is reduced	deg. F	35	45	32	48	40	40	Climate, vegetation
PETMIN	Temp below which ET is set to zero	deg. F	30	35	30	40	35	35	Climate, vegetation
INFEXP	Exponent in infiltration equation	none	2	2	1	3	2	2	Soil properties
INFILD	Ratio of max/mean infiltration capacities	none	2	2	1	3	2	2	Soil properties
DEEPFR	Fraction of GW inflow to deep recharge	none	0	0.2	0	0.5	0.1	0	Geology
BASETP	Fraction of remaining ET from baseflow	none	0	0.05	0	0.2	0.02	0.0-0.02[1]	Riparian vegetation
AGWETP	Fraction of remaining ET from active GW	none	0	0.05	0	0.2	0	0	Marsh/wetlands ET
PWAT-PARM4									
CEPSC	Interception storage capacity	inches	0.03	0.2	0.01	0.4	0.1	monthly[1]	Vegetation
UZSN	Upper zone nominal soil moisture storage	inches	0.10	1	0.05	2	1.128	0.235-2.05[1]	Soil properties
NSUR	Mannings' n (roughness)	none	0.15	0.35	0.1	0.5	0.2	0.06-0.09[1]	Landuse, surface condition
INTFW	Interflow/surface runoff partition parameter	none	1	3	1	10	0.75	1.4	Soils, topography, land use
IRC	Interflow recession parameter	none	0.5	0.7	0.3	0.85	0.5	0.3	Soils, topography, land use
LZETP	Lower zone ET parameter	none	0.2	0.7	0.1	0.9	monthly	monthly[1]	Vegetation
QUAL-INPUT									
ACQOP	Rate of accumulation of constituent	#/day						monthly[1]	Land use
SQOLIM	Maximum accumulation of constituent	#						9 x ACQOP	Land use
WSQOP	Wash-off rate	in/hr						1.8	Land use
IOQC	Constituent conc. in interflow	$\#/ft^3$						2832	Land use

[1] Varies with land use

Table 7.16. Input parameters used in HSPF simulations for the Little Otter River (Continued).

			RANGE OF VALVES						
PARAMETER	**DEFINITION**	**UNITS**	**TYPICAL**		**POSSIBLE**		**START**	**FINAL**	**FUNCTION OF…**
PERLIND			**MIN**	**MAX**	**MIN**	**MAX**		**CALIB.**	
AOQC	Constituent conc. in active groundwater	#/ft^3						1416	Land use
IMPLND									
IWAT-PARM2									
LSUR	Length of overland flow	feet	200	500	100	700	300	300	Topography
SLSUR	Slope of overland flowplane	none	0.01	0.15	0.001	0.3	0.035	0.01	Topography
NSUR	Mannings' n (roughness)	none	0.15	0.35	0.1	0.5	0.2	0.05	Land use, surface condition
RETSC	Retention/interception storage capacity	inches	0.03	0.2	0.01	0.4	0.1	0.065	Land use, surface condition
IWAT-PARM3									
PETMAX	Temp below which ET is reduced	deg. F	35	45	32	48	40	40	Climate, vegetation
PETMIN	Temp below which ET is set to zero	deg. F	30	35	30	40	35	35	Climate, vegetation
IQUAL									
ACQOP	Rate of accumulation of constituent	#/day						1.00E+07	Land use
SQOLIM	Maximum accumulation of constituent	#						3.00E+07	Land use
WSQOP	Wash-off rate	in/hr						1.8	Land use
RCHRES									
HYDR-PARM2									
KS	Weighting factor for hydraulic routing							0.5	
GQUAL									
FSTDEC	First order decay rate of the constituent	1/day						1.15	
THFST	Temperature correction coeff. for FSTDEC							1.05	

[1] Varies with land use

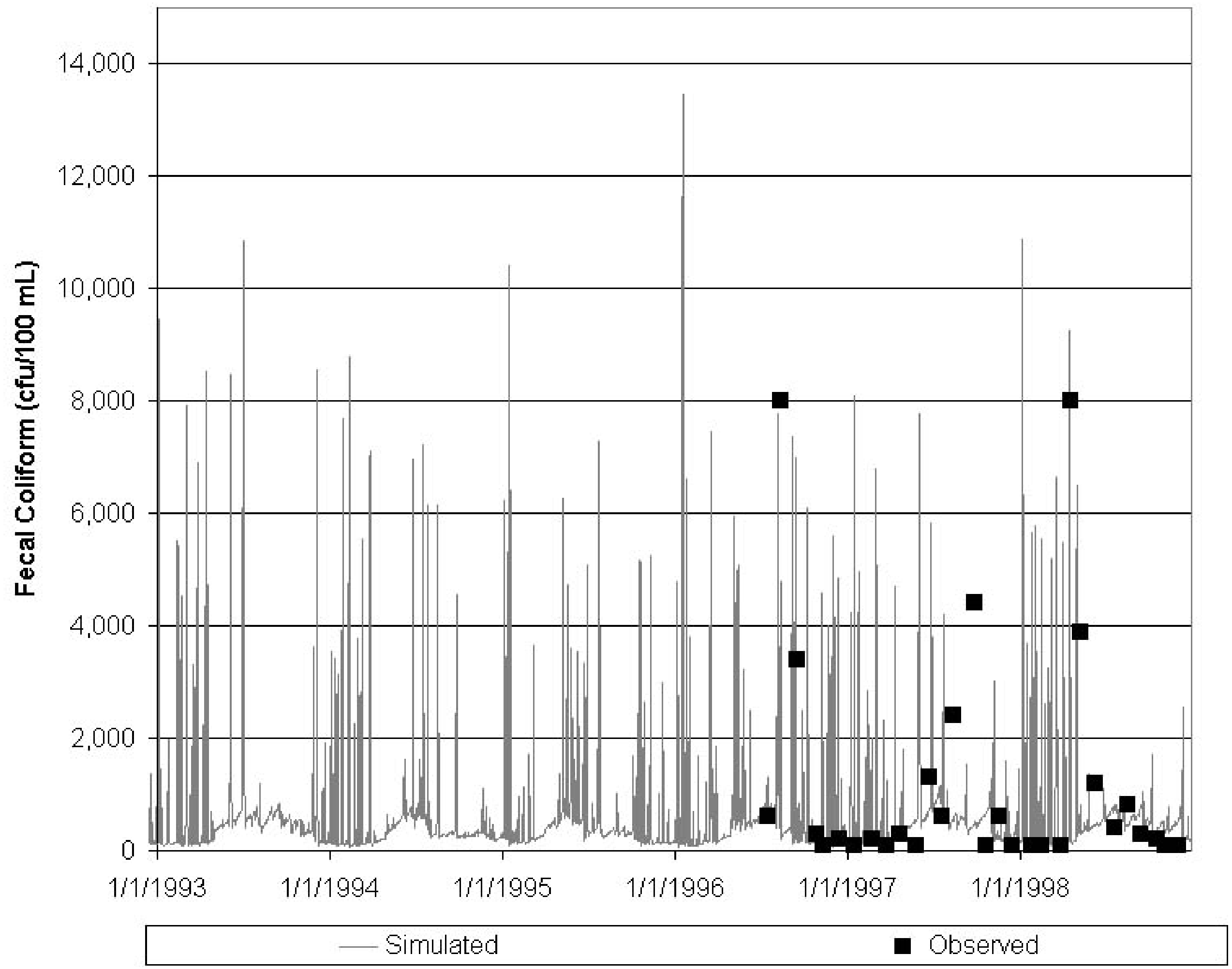

Figure 7.3. Simulated and observed fecal coliform concentrations for the Little Otter River VADEQ station 4ALOR008.64.

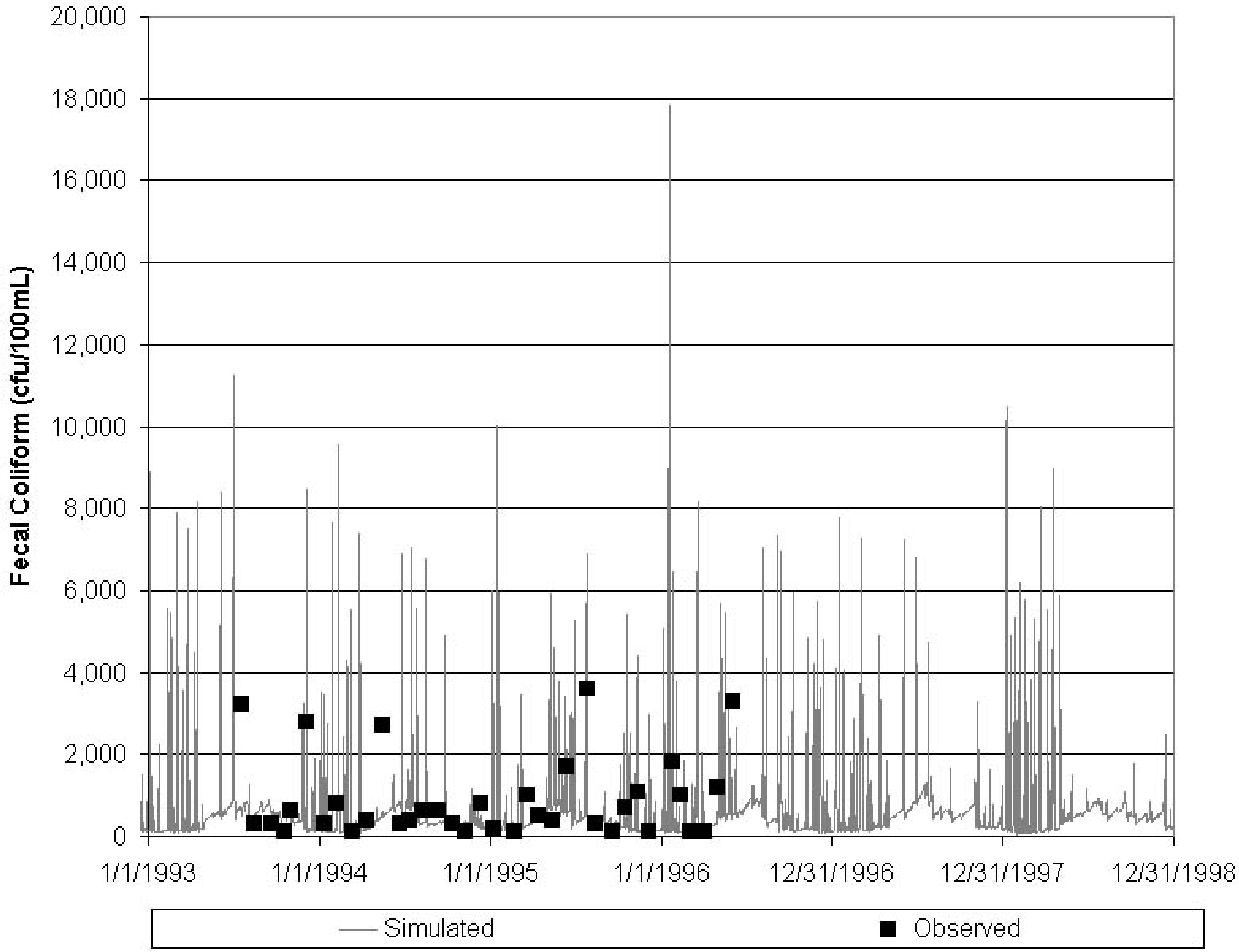

Figure 7.4. Simulated and observed fecal coliform concentrations for the Little Otter River VADEQ station 4ALOR0010.78.

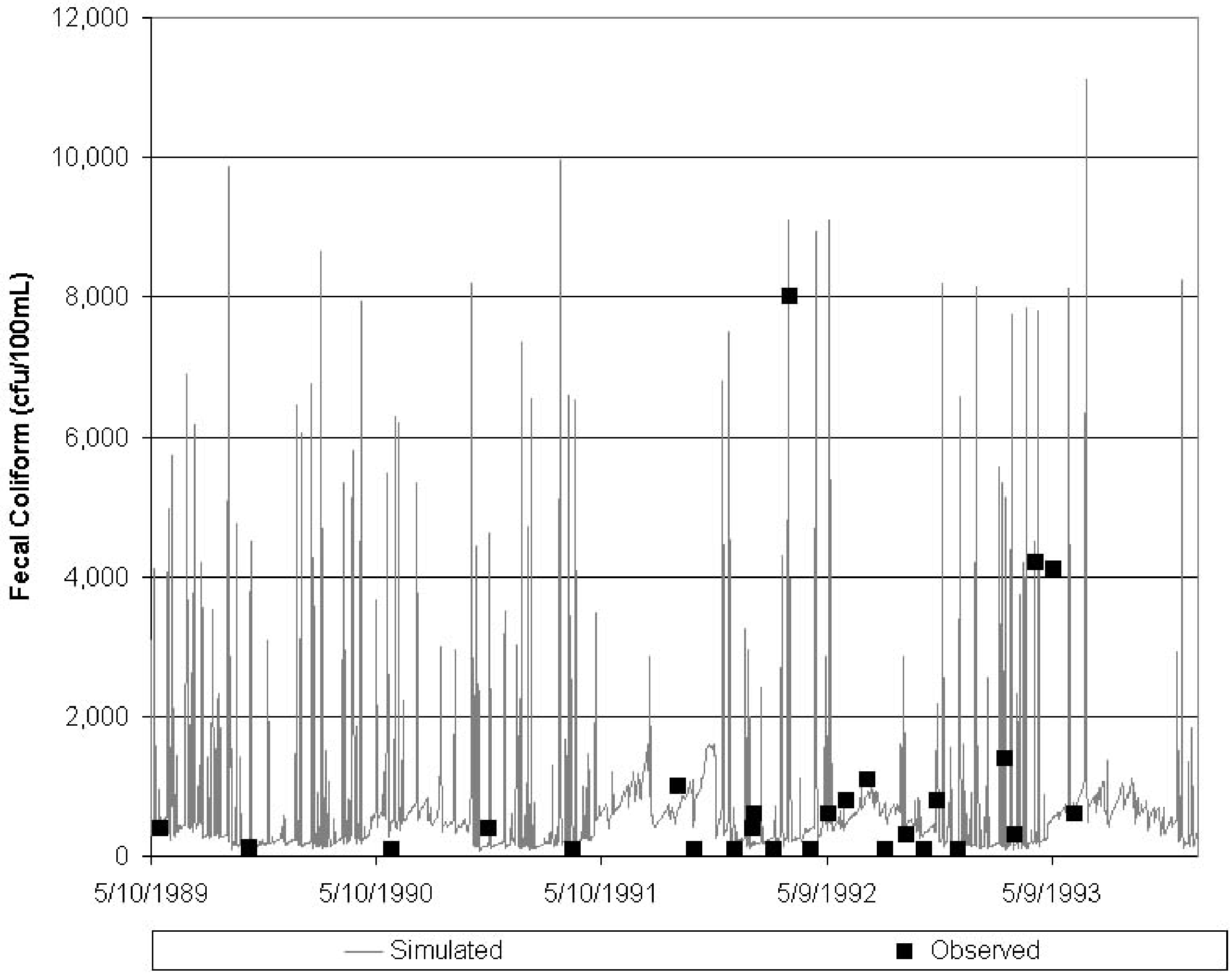

Figure 7.5. Simulated and observed fecal coliform concentrations for the Little Otter River VADEQ station 4ALOR0014.33.

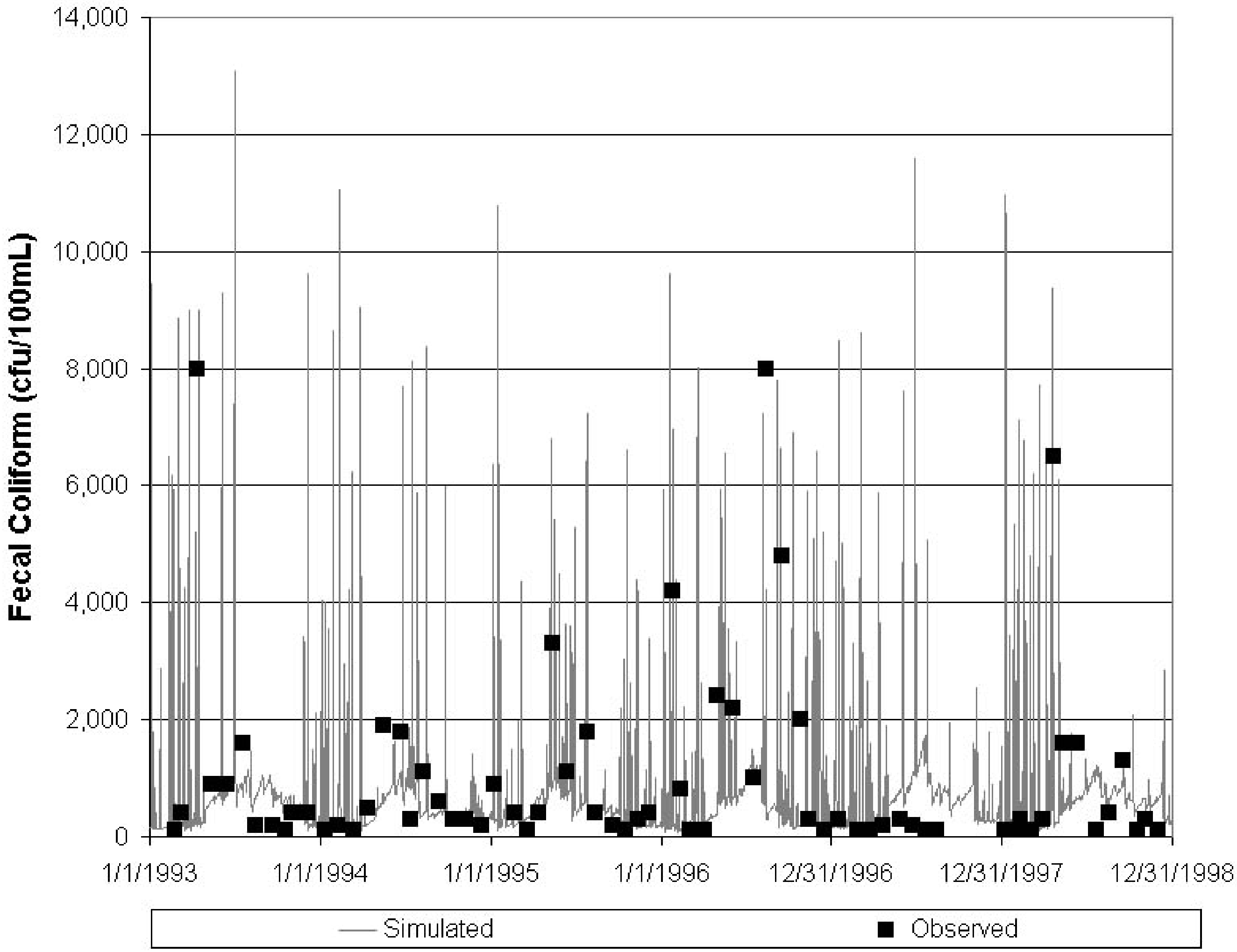

Figure 7.6. Simulated and observed fecal coliform concentrations for the Little Otter River VADEQ station 4ALOR0014.75.

7.4 Load Allocations

7.4.1 Background

The objective of a TMDL is to allocate allowable loads among different pollutant sources so that the appropriate control actions can be taken to achieve water quality standards (USEPA, 1991). The objective of the TMDL for the Little Otter River is to determine what reductions in fecal coliform loadings from point and nonpoint sources are required to meet state water quality standards. The Little Otter River receives pollutants from the Little Otter River watershed as well as from the Machine Creek watershed, which is tributary to the Little Otter River. In developing the TMDL plan, water quality was simulated at four points within the impaired segment and the final TMDL was developed for the stream reach that was the most restrictive (required the greatest reductions in loadings to meet the water quality standard). For the Little Otter River watershed, the most restrictive stream reach was located between the State Route 43 bridge over the Little Otter River and the confluence of Johns Creek with the Little Otter River. Load reductions were applied uniformly across the entire watershed (except in Machine Creek).

The state water quality standard for fecal coliform used in the development of the TMDL was the 30-day geometric mean standard of 200 cfu/100mL. The TMDL considers all sources contributing fecal coliform to the Little Otter River. The sources can be separated into nonpoint and point (or direct) sources. The incorporation of the different sources into the TMDL are defined in the following equation:

$$TMDL = WLA + LA + MOS \qquad [7.1]$$

where,

WLA	=	waste load allocation (point source contributions);
LA	=	load allocation (nonpoint source contributions); and
MOS	=	Margin of safety.

A MOS is included to account for any uncertainty in the TMDL development process. There are several ways that the MOS can be incorporated into the TMDL (USEPA, 1991). For the Little Otter River TMDL, a MOS of 5% (i.e. MOS = 10 cfu/100mL) was used. By subtracting the MOS from the TMDL standard of 200 cfu/100mL, the goal of the TMDL allocation was that the combined point source (WLA) and nonpoint source (LA) loads be below the target fecal coliform concentration (30-day geometric mean) of 190 cfu/100mL.

The time period selected for calibration and load allocation was January 1, 1993 to December 31, 1998. This period incorporates a wide range of hydrologic events including both low and high flow conditions, and is also a period for which observed data were available.

7.4.2 Calibration Period and Existing Conditions

Analysis of the simulation results for the calibration period (Table 7.17) shows that fecal coliform loads from Machine Creek contribute significantly to the total load at the watershed outlet, accounting for about 46% of the total mean daily fecal coliform concentration at the Little Otter River watershed outlet. Loads from PLS on average contribute about 36% of the mean daily fecal coliform concentration, while loads from the direct deposition by cattle and wildlife are responsible for an average of about 12% and 4%, respectively. The other sources, the City of Bedford STP, straight pipes, interflow, and groundwater together contribute about 1% of the mean daily concentration.

Table 7.17. Relative contributions of different fecal coliform sources to the overall mean fecal coliform concentration during the calibration period.

Fecal Coliform Source	Mean Daily Fecal Coliform Concentration Attributable to Sources, (cfu/100mL)	Relative Contribution by Source %
Baseline -- All Sources	870	100
Direct Deposit from Cattle only	108	12.41
Direct Deposit from Wildlife only	37	4.25
Straight Pipe Discharge only	1	0.11
Bedford STP Overflows	7	0.8
Inflow from Machine Creek	401	46.1%
Loads from Permitted Points Sources only	0	0
Loads from PLS Only	315	36.22
Loads from ILS Only	0	0
Interflow (10cfu/100mL) and Groundwater (5cfu/100mL) only	1	0.11

The simulation of existing conditions provides the baseline for evaluating reductions required for the TMDL allocation. Cattle populations were reduced for the existing condition simulations, compared to the calibration period. The cattle population during the calibration period represented the average cattle populations in the watersheds from 1993 to 1998. The existing condition cattle populations account for the known decreases in dairy cattle populations during the last three to four years. Fecal coliform loads (NPS and direct NPS) used in the development of the TMDL allocation represent the cattle populations for "existing conditions". Table 7.18 gives the concentrations of fecal coliform from direct nonpoint sources for the existing conditions.

Simulated 30-day mean fecal coliform concentrations in the Little Otter River due to existing Little Otter River loads are shown in Figure 7.7 along with the geometric mean standard. Simulated concentrations are always above the geometric mean standard. The concentration of fecal coliform is higher during the summer months due to reduced dilution during low-flow conditions.

Table 7.18. Fecal coliform loads for the Little Otter River from direct nonpoint sources.

Source	Fecal coliform loads ($\times 10^{12}$ cfu/year)	Percent of total loading
Cattle in stream	130.4	75.29
Wildlife in stream	41.0	23.68
Straight pipes	1.8	1.03
Total	**173.2**	**100.0**

Direct deposits by cattle are a critical source, especially during the summer, when increased time spent in streams corresponds with the decreased dilution associated with low stream flow. In summer months, It is estimated that cattle with access to streams spend two hours per day in water (Table 2.8). Hence, of the 810 cattle on pastures with stream access, an equivalent of 68 cattle spend the entire day in the stream. With the estimate that 30% of the feces of these cattle is deposited directly to the streams, the waste equivalent of 20 cattle is deposited directly in the streams. This represents approximately 2.5% of the manure load of cattle in pastures with stream access. The fraction of manure directly deposited in the stream at other times of the year is lower, but can still contribute to water quality standard exceedances during low-flow periods.

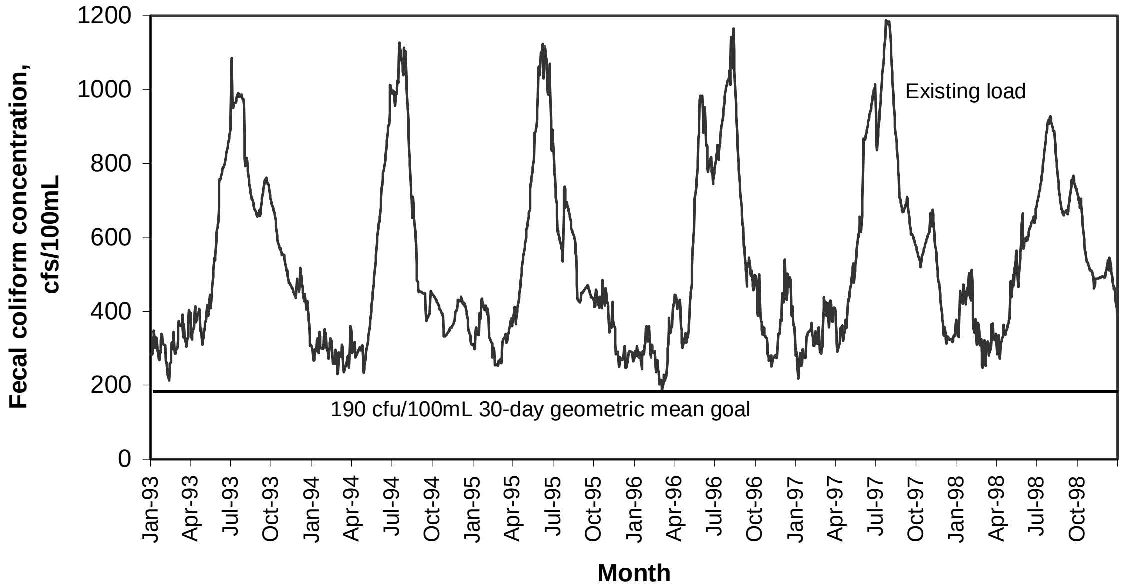

Figure 7.7. Simulated 30-day mean fecal coliform concentrations in the Little Otter River (at the outlet of the watershed) due to existing fecal coliform loads.

7.4.3 Allocation Scenarios

Several allocation scenarios were evaluated, and as shown in Table 7.19, only the most restrictive scenario (11) meets the TMDL allocation requirement of no violations of the 190 cfu/100mL 30-day geometric mean goal. Loads from straight pipes and the Bedford STP were reduced by 100% for all scenarios. In addition to those reductions, direct deposition from cattle was reduced by 90%, 99% and then 100% in scenarios 2, 3, and 4, respectively, and still resulted in relatively high percentage violations of the 190cfu/100mL 30-day geometric mean goal. Therefore, reductions were made in direct wildlife deposits and NPS from land segments. Reductions in contributions from wildlife were inevitable because direct deposits by wildlife and NPS loadings from pervious land segments alone caused 18% violation of the 30-day geometric mean standard. These standards exceedances are primarily the result of direct deposits by wildlife during low flow periods when NPS loading have little impact. Even with no sources other than wildlife and NPS loadings from pervious land segments, a 60% reduction in direct deposits by wildlife was required to reduce violations of the 30-day geometric mean standard to 5.3% (scenario 6, Table 7.19.). Scenarios 5 through 11 show different percentages of reductions from direct wildlife deposits and NPS loadings from pervious land segments and the resulting percentage of violations of the 190cfu/100mL 30-day geometric mean goal. Scenario 11, which requires a

70% reduction in direct wildlife deposition to streams, a 60% reduction in NPS from all pervious land segments except forest, and total elimination of direct deposits from cattle in streams, straight pipes and the City of Bedford CSO, meets the TMDL goal.

Table 7.19. Fecal coliform TMDL allocation scenarios for the Little Otter River

Scenario Number	Percent reduction in loading from existing condition[1]					Percentage of days with 30-day GM > 190 cfu/100mL
	Direct wildlife deposits	Direct cattle deposits	NPS from pervious land segments	Direct pipes	Bedford CSO	
1	0	0	0	100	100	100.0%
2	0	90	0	100	100	62.0%
3	0	99	0	100	100	41.2%
4	0	100	0	100	100	38.3%
5	50	100	0	100	100	7.9%
6	60	100	0	100	100	5.3%
7	60	100	25[1]	100	100	2.8%
8	60	100	50[1]	100	100	0.6%
9	60	100	50[2]	100	100	0.2%
10	70	100	50[2]	100	100	0.1%
11	**70**	**100**	**60[2]**	**100**	**100**	**0.0%**

[1] NPS reductions from pasture and cropland only

[2] NPS reduction from all pervious land segments except forest

Bold indicates the scenario selected

Table 7.20 shows the loads from nonpoint sources for all pervious land segments and the results of the 60% reduction called for by the TMDL allocation scenario (scenario 11 in Table 7.19). The reductions in direct nonpoint loads required by allocation scenario 11 are shown in Table 7.21. The graph of 30-day geometric mean fecal coliform concentrations for existing conditions and for the selected TMDL allocation scenario (Figure 7.8) shows that simulated concentrations do not exceed the geometric mean goal of 190 cfu/100mL for the allocation study period.

Table 7.20. Annual nonpoint source loads to the Little Otter River under existing conditions and corresponding reductions for TMDL allocation scenario 11.

Land use Category	Existing conditions		Allocation scenario	
	Existing load (× 10^{12} cfu)	Percent of total load to stream from nonpoint sources	TMDL nonpoint source allocation load (× 10^{12} cfu)	Percent reduction from existing load
Commercial/ Industrial	0.01	< 0.1	0.01	0
Cropland	0.11	< 0.1	0.04	60
Forest	8.14	0.2	8.14	0
High Density Residential	78.11	2.4	78.11	0
Pasture	3,136.00	96.6	1,254.40	60
Rural Residential	24.87	0.8	24.87	0
Total	**3,247.24**	**100.0**	**1,365.57**	**58.0**

Table 7.21. Annual direct nonpoint source loads to the Little Otter River under existing conditions and corresponding reductions for TMDL allocation scenario 11.

Source	Existing Conditions		Allocation Scenario	
	Fecal Coliform load (× 10^{12} cfu/year)	Percent of total load to stream from direct nonpoint sources	Nonpoint source allocation load* (× 10^{12} cfu/year)	Percent reduction
Cattle in stream	130.4	75.29	0.00	100.0
Wildlife in stream	41.0	23.68	12.30	70.0
Straight pipes	1.8	1.03	0.00	100.0
Total	**173.2**	**100.0**	**12.30**	**92.9**

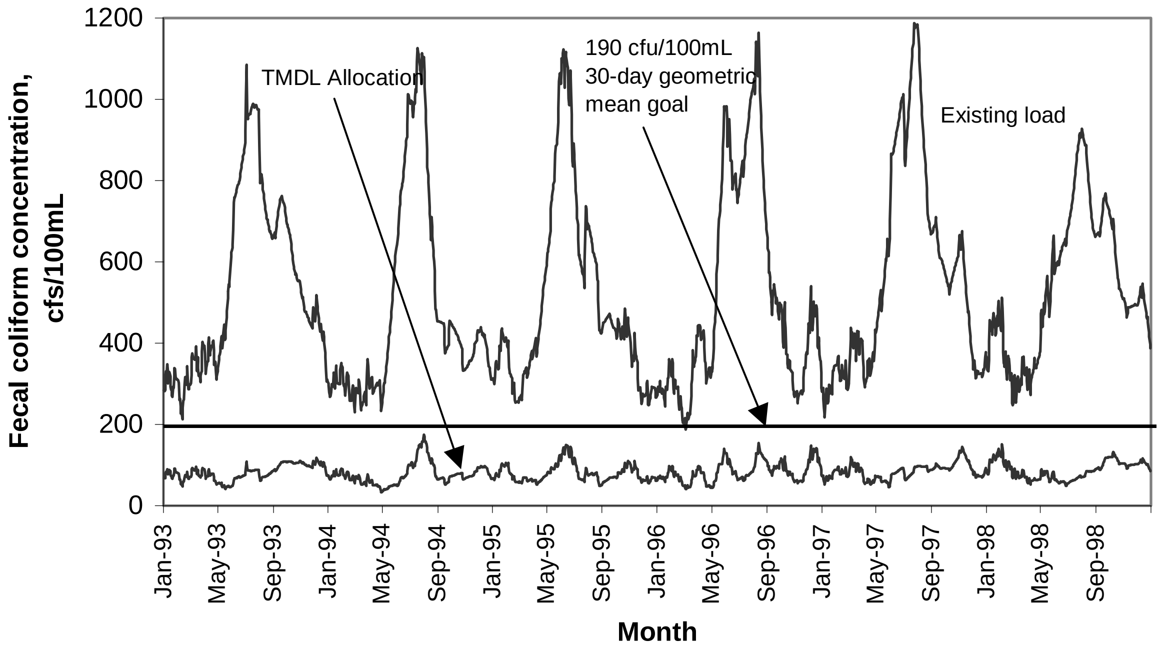

Figure 7.8. Predicted 30-day geometric mean fecal coliform concentrations for the Little Otter River (at the watershed outlet) for existing conditions and for loads reduced according to the TMDL allocation plan.

7.4.4 Summary of TMDL Allocation

A TMDL for fecal coliform has been developed for the Little Otter River. The TMDL addresses the following issues.

1 The TMDL meets the water quality standard of no exceedances of the 30-day geometric mean fecal coliform concentration of 200 cfu/100 mL..

2 A MOS of 5% was incorporated in the development of the TMDL plan.

3 The TMDL accounts for fecal coliform from human, domestic/agricultural animals, and wildlife sources.

4 Both high and low-flow stream conditions were considered in developing the TMDL. In the Little Otter River watershed, low flow conditions were found to be the environmental condition most likely to cause a violation of the 30-day geometric mean.

5 Both the flow regime and fecal coliform loadings are seasonal, with higher loadings and in-stream concentrations during the summer than in the winter. The TMDL accounts for these seasonal effects.

6 A TMDL allocation plan to meet the 30-day geometric mean water quality goal of 190 cfu/100mL requires: a 100% reduction in direct deposits of cattle manure to streams, a 70% reduction in direct deposits by wildlife to streams, and a 60% reduction in NPS loadings from all pervious land uses except forest. The annual fecal coliform loads for the selected TMDL allocation scenario are summarized in Table 7.22.

Table 7.22. Annual fecal coliform allocation (cfu/year) for the Little Otter River watershed fecal coliform TMDL.

Subwatershed	Point Source Loads	Nonpoint Source Loads[a]	Margin of Safety[b]	TMDL Annual Load
Little Otter	6.8×10^{12}	$1{,}377.7 \times 10^{12}$	72.9×10^{12}	$1{,}457.4 \times 10^{12}$

a with LA from Machine Creek inflow of 849.4×10^{12} cfu/year

b Five percent of TMDL

8 TMDL FOR LOWER BIG OTTER RIVER WATERSHED

8.1 Watershed Characterization

8.1.1 Water Resources

The Lower Big Otter River HU (L28) has 32.4 miles of primary and secondary streams. In addition to the BOR, Johnson Creek, Tardy Branch, and Troublesome Creek form part of the HU's stream network (Figure 8.1). The BOR discharges into the Roanoke River. The HU is located in the Piedmont physiographic province, with moderate to low groundwater pollution potential (VWCB, 1985). The seasonal high water table in the watershed is generally deeper than 5 ft from the mineral soil surface (SCS, 1977).

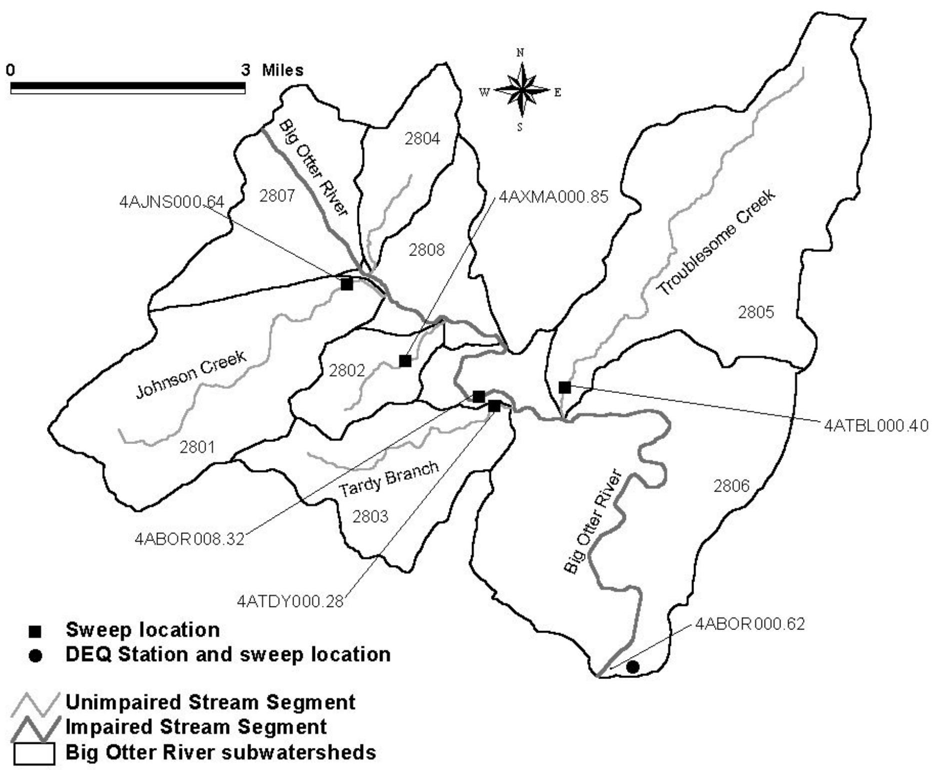

Figure 8.1. Lower Big Otter River (L28) subwatersheds, stream network, locations of VADEQ water quality monitoring sites and sweep sites for flow and water quality monitoring

8.1.2 Soils

The five soil associations found in the Lower Big Otter River HU (L28) are Madison-Tallapoosa, Tatum-Manteo-Nason, Cullen-Willkes, Georgeville-Tatum, and Cecil-Appling. The Madison-Tallapoosa soils are found in the headwaters. The Tatum-Manteo-Nason soils are the most dominant in the watershed. Detailed descriptions of these soil associations are given in Section 2.5.2.

8.1.3 Land use

The HU was divided into eight subwatersheds to spatially analyze fecal coliform distribution within the HU (Figure 8.1). Land use distribution in the subwatersheds and the entire Lower Big Otter River HU (L28) is presented in Table 8.1. The HU is largely forested (72.7%), while pastures account for 19.0% of the acreage.

Table 8.1. Land use distribution (acres) among the subwatersheds of the Lower Big Otter River HU (L28)

Land use	Subwatershed								Total[a]	
	2801	2802	2803	2804	2805	2806	2807	2808	Acres	%
Commercial/ industrial	15	0	32	28	23	66	0	22	186	0.7
Cropland	0	31	23	23	79	143	53	140	492	1.8
Forest	3,340	388	1,913	648	4,565	6,221	2,089	945	20,109	72.7
High density residential	13	1	20	47	448	204	10	9	752	2.7
Pasture	701	613	540	316	1,087	1,174	346	484	5,261	19.0
Rural residential	41	3	19	136	387	138	103	18	845	3.1
Total[a]	**4,110**	**1,036**	**2,547**	**1,198**	**6,589**	**7,946**	**2,601**	**1,618**	**27,644**	**100.0**

[a] Component acreages may not add up due to round-off error.

8.1.4 Flow and Water Quality Data

Historic data

No historic flow data are available for the Lower Big Otter River HU. The VADEQ collected water quality samples at monitoring station 4ABOR000.62 (Figure 8.1) during September 1988 until December 1998. The water quality samples were analyzed for fecal coliform using the MFT with a maximum concentration cap of 8,000 cfu/100 mL. Even though most samples were collected at monthly intervals, the sampling interval exceeded three months for many samples collected during 1988 through 1992, with some missing monthly data points during 1993 through 1994. Monitoring site 4ABOR000.62 is located on the downstream end of the impaired section of the Lower Big Otter River. Time series data of fecal coliform concentration observed at 4ABOR000.62 are presented in Figure 8.2.

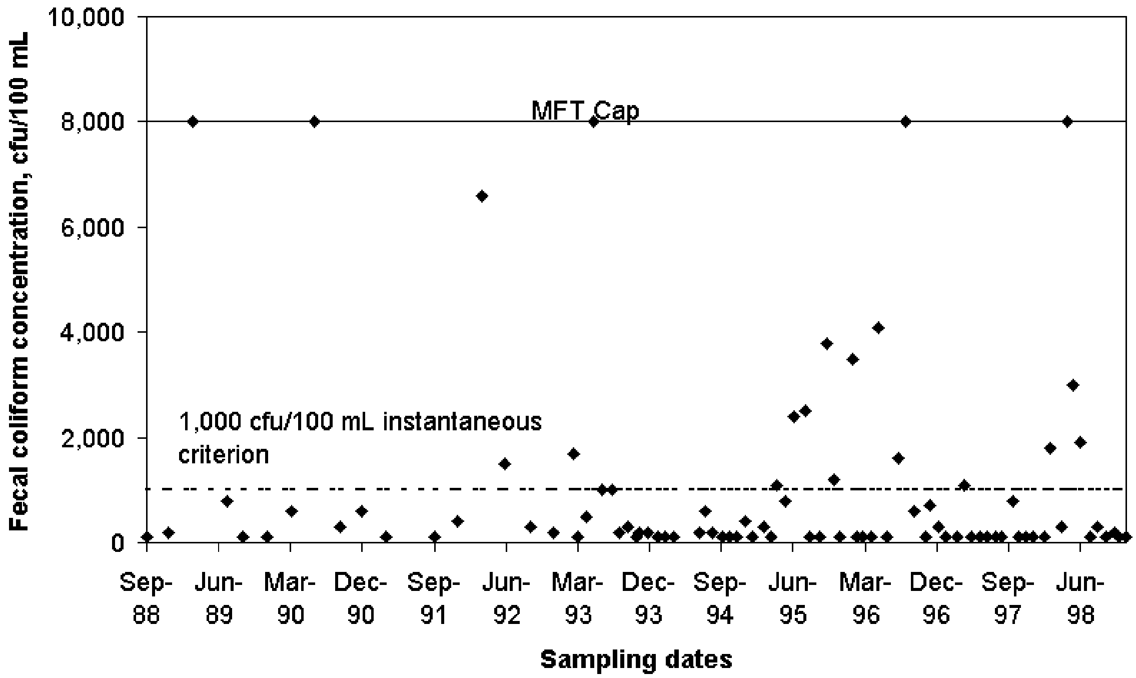

Figure 8.2. Time series (September 1998 - December 1998) of fecal coliform concentration observed in VADEQ monitoring station 4ABOR000.62 on the Lower Big Otter River

More than 23% of the samples exceeded the instantaneous standard of 1,000 cfu/100 mL. Five of 86 samples had fecal coliform concentration of 8,000 cfu/100 mL (MFT cap), indicating that the actual concentration could have been higher. Given the lack of flow data, no inferences could be made regarding the impact of flow on fecal coliform concentration. During 1995 through 1998, seasonality of fecal coliform concentration in the Lower Big Otter River was evaluated in terms of mean monthly values (Figure 8.3).

Higher fecal coliform concentrations observed during April through August could be due to cattle spending more time in the stream due to the warm weather resulting in greater direct manure and, hence, fecal coliform loading to the stream. However, the reason for lower fecal coliform concentrations during June and July compared with April, May, and August is unclear since cattle are likely to spend more time in the stream during June and July, which are warmer than April and May. Lower fecal coliform during the winter months (December – February) was expected since cattle are likely to spend less time in the stream. However, the reason for high fecal coliform concentration during January (which is the coldest month) compared to December and February was unclear. The impact of other fecal coliform sources on the seasonality of fecal coliform concentration (Figure 8.3) is unclear.

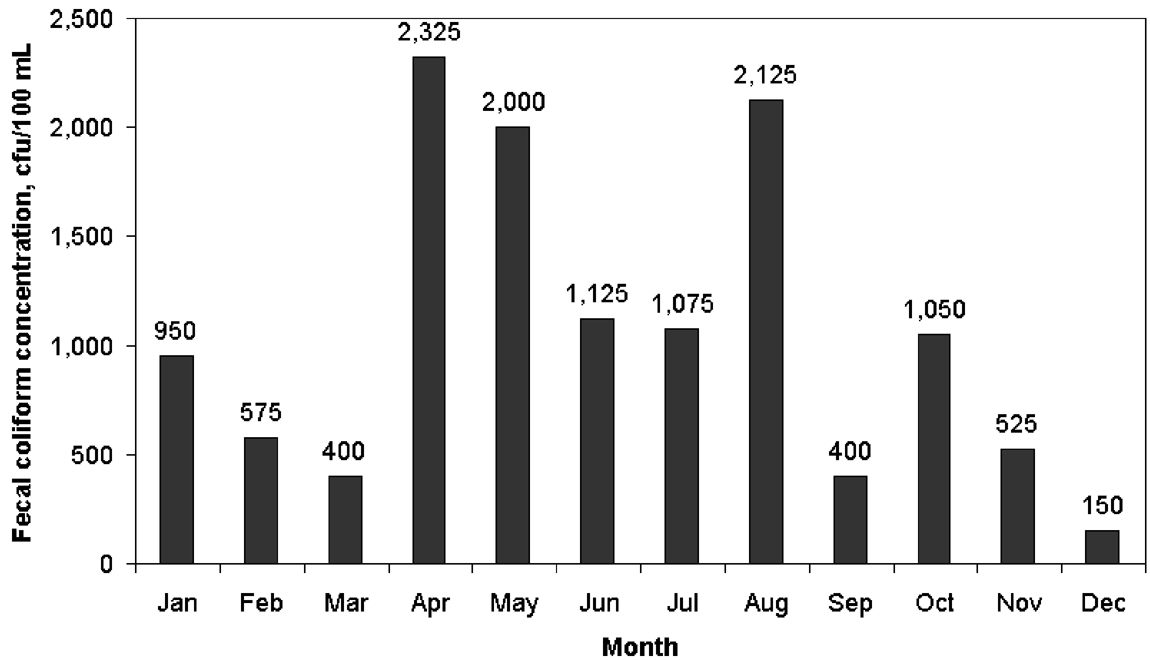

Figure 8.3. Average mean monthly fecal coliform concentration over a four-year period (1995-1998) observed in VADEQ monitoring station 4ABOR000.62 on the Lower Big Otter River

Water quality sweep and flow measurement

The VADEQ and Virginia Tech conducted a water quality and flow monitoring sweep on March 20-22, 2000. The purpose of the sweep was to assess water quality conditions at various stations within the Lower Big Otter River HU (L28). The following factors were considered in selecting the monitoring sites for conducting the sweep.

- Water quality at the monitoring site should be representative of the impact of Land use practices immediately upstream of the site;

- the monitoring site should be in close proximity to a road or bridge so that the site would be located on public land with easy access; and

- the monitoring site should be located at the outlet of a subwatershed.

Six monitoring sites were selected that met the criteria. The sites are described in Table 8.2 and their locations are indicated in Figure 8.1.

Table 8.2. Location and description of sampling sites for instantaneous water quality and flow assessment

ID	Stream	Location
4AJNS000.64	Johnson Creek	Bridge on Rt. 626 near intersection of Rt. 626 and Rt. 682 near the confluence of Johnson Creek and the Big Otter River
4AXMA000.85	Big Otter River SW	Bridge on Rt. 626, north of intersection of Rt. 626 and Rt. 711
4ABOR008.32	Big Otter River	Across pasture from end of Rt. 709, below remnants of abandoned stone trestle; near confluence of Big Otter River and Tardy Branch
4ATDY000.28	Tardy Branch	Bridge on Rt. 711 east of intersection of Rt. 711 and Rt. 626, near confluence of Tardy Branch and Big Otter River
4ATBL000.40	Troublesome Creek	Ford of gravel farm road between feedlot and barn on Rt. 709 south of intersection of Rt. 709 and Rt. 696
4ABOR000.62	Big Otter River	Bridge on Rt. 712, near intersection of Rt. 712 and US Rt. 29

At each site, staff from VADEQ collected two water samples, one from below the stream surface and another at the bottom of the stream (after disturbing the streambed). Samples were stored on ice and were analyzed for fecal coliform within 24 hours using the MPN method by the DCLS in Richmond. The MPN method used a maximum detection limit of 160,000 cfu/100 mL. Flow rate was calculated by multiplying the flow velocity (measured with a current meter) with the measured channel cross-sectional area. The results of the sweep are presented in Table 8.3.

In the seven days preceding the sweep, a total of 1.67 inches of precipitation was recorded at Lynchburg Regional Airport with 1.17 inches of the amount recorded in the preceding 48 hours. Fecal coliform concentrations in the stream surface and bottom samples exceeded the instantaneous standard at four and three sites, respectively. Both monitoring sites on the Lower Big Otter River had fecal coliform concentrations that did not exceed the instantaneous standard of 1,000 cfu/100 mL (Table 8.3). However, water samples at all of the Lower Big Otter River's tributaries indicated that the instantaneous standard was exceeded in the surface sample. Greater fecal coliform concentrations in the tributaries could be due to low-flow conditions (Table 8.3) resulting in little dilution.

Table 8.3. Results of the instantaneous fecal coliform and flow assessment

ID	Stream	Flow (cfs)	Fecal coliform counts (cfu/100 mL)	
			Stream surface[a]	Stream bottom[b]
4AJNS000.64	Johnson Creek	3.8	54,000	780
4AXMA000.85	Big Otter River SW	0.5	1,700	4,900
4ABOR008.32	Big Otter River	214.0	200	180[c]
4ATDY000.28	Tardy Branch	2.5	1,700	4,900
4ATBL000.40	Troublesome Creek	6.0	1,300	2,300
4ABOR000.62	Big Otter River	233.0	200	680

[a] Sample was obtained from just below the stream surface.

[b] Stream bottom was stirred prior to sample collection.

[c] Lower limit of detection

8.2 Source Assessment of Fecal Coliform

Procedures used in quantifying fecal coliform sources are discussed in Section 2.6. Specific information for the Lower Big Otter River HU is presented in the following sections.

8.2.1 Point Sources

There are no permitted point sources in the Lower Big Otter River HU.

8.2.2 Nonpoint Source

Nonpoint sources of fecal coliform in the Lower Big Otter River HU include humans, pets, livestock, and wildlife. Fecal coliform directly deposited in the stream by any source is characterized as a direct nonpoint source while fecal coliform applied or deposited on the land is termed as nonpoint source.

Humans

Based on an average household size of 2.5 persons, the Lower Big Otter River HU has an estimated total human population of 2,458. Distribution of human population among the subwatersheds is shown in Table 8.4.

Table 8.4. Distribution of human and pet populations in the Lower Big Otter River HU (L28)

Subwatershed	Human population	Pet population
2801	155	62
2802	40	16
2803	145	58
2804	272	109
2805	1,098	439
2806	620	248
2807	80	32
2808	48	19
Total	**2,458**	**983**

Failing septic systems

Based on an average household size of 2.5 persons and fecal coliform production of 1.95×10^9 cfu/day, a typical failing septic system contributes 4.88×10^9 cfu/day to the rural residential land use. The numbers of failing septic systems in the subwatersheds of the Lower Big Otter River HU (L28) are shown in Table 8.5.

Table 8.5. Estimated number of unsewered households by age, number of failing septic systems, and straight pipes in the Lower Big Otter River HU (L28)

Subwater-shed	Unsewered houses by age (no.)				Failing septic systems (no.)	Straight pipes (no.)
	Pre-1967	1967-1985	Post-1985	Total		
2801	38	23	1	62	20	0
2802	13	3	0	16	6	0
2803	25	33	0	58	17	0
2804	86	23	0	109	39	0
2805	206	233	0	439	129	1
2806	137	111	0	248	77	0
2807	14	16	2	32	9	0
2808	18	1	0	19	7	0
Total	**537**	**443**	**3**	**983**	**304**	**1**

Biosolids

No biosolids applications were made in the HU during 1990-1998. As described in Chapter 3, the 1990-1998 period was considered in evaluating fecal coliform loading under existing conditions.

Straight pipes

A household with a straight pipe contributes 4.88×10^9 cfu/day (household size multiplied by daily fecal coliform production) directly into the stream. It is estimated that there is one straight pipe in the HU (Table 8.5).

Pets

Based on the assumption of one pet per household, the number of pets in each subwatershed of the Lower Big Otter River HU (L28) was calculated (Table 8.4). There is no fecal coliform loading from pets to the high-density residential land use in this HU because this land use is comprised of urban and built-up land without any residences. The entire pet loading is applied to the rural residential land use by multiplying the number of pets by the fecal coliform produced by a pet (450×10^6 cfu/day).

Livestock

Beef cattle

Beef cattle in the Lower Big Otter River HU were distributed among the subwatersheds based on their pasture acreages. The number of beef cattle in each subwatershed is shown in Table 8.6.

Dairy cattle

Distribution of dairy cattle among the subwatersheds is given in Table 8.6. As discussed in Section 2.6, the pre-1996 dairy numbers are based on 1987 and 1992 Agricultural Census and were used for the calibration simulations. The current dairy numbers were used for simulating the allocation scenarios.

Horses

Horses were distributed among the subwatersheds based on their pasture acreages. Distribution of horses among the subwatersheds is given in Table 8.6.

Table 8.6. Distribution of beef cattle, dairy cattle, and horses among the subwatersheds in the Lower Big Otter River HU (L28)

Subwatershed	Beef	Dairy[a]		Horses
		Pre-1996	Current	
2801	161	160	0	15
2802	141	0	0	13
2803	124	0	0	12
2804	73	0	0	7
2805	250	160	160	24
2806	270	0	0	25
2807	80	0	0	8
2808	111	0	0	10
Total	**1,210**	**320**	**160**	**114**

[a] Includes milk cows, dry cows, and heifers

Direct manure deposition in streams

Manure deposition in streams is affected by the number of beef and dairy cattle in the watershed as well as the percent of acres with stream access. The percentage of pasture with stream access in each subwatershed (Table 8.7) of the Lower Big Otter River HU was calculated using the procedure given in Section 2.6.

Table 8.7. Percentage of pasture with stream access in the subwatersheds of the Lower Big Otter River HU (L28)

Subwatershed	Percent of pasture with stream access
2801	39
2802	58
2803	67
2804	70
2805	48
2806	37
2807	37
2808	66
Average	**53**

While milk cows are confined part of the year, dry cows, heifers, and beef cattle are not confined. When not confined, milk cows as well as other cattle deposit their waste on pasture and into streams. Monthly distribution of cattle in confinement, on pasture, and in streams in the Lower Big Otter River HU (Table 8.8) was calculated based on the confinement schedule for milk cows (Table 2.8), time spent by cattle in the stream (Table

2.8), and percent of pasture with stream access (Table 8.7). Cattle in the stream (Table 8.8) represent the number of cattle defecating in the stream, assuming that 30% of the cattle in and around the stream defecate in the stream.

Fecal coliform deposition in the stream by dairy and beef cattle was calculated by multiplying the number of cattle in the stream by fecal coliform production (Table 2.4). Total fecal coliform deposition was calculated by adding the fecal coliform production of the dairy and beef cattle defecating in the stream. Annual fecal coliform loadings to the streams in the subwatersheds of the Lower Big Otter River HU by dairy and beef cattle are given in Table 8.9.

Table 8.8. Monthly distribution of dairy and beef cattle among confinement, pasture, and stream in the Lower Big Otter River HU (L28)

Month	Dairy[a]			Beef		Total	
	Confined[b]	Pasture	Stream	Pasture	Stream	Dairy[a]	Beef
January	81 (40)	239 (120)	0 (0)	1,206	4	320 (160)	1,210
February	81 (40)	239 (120)	0 (0)	1,206	4	320 (160)	1,210
March	47 (24)	272 (136)	1 (0)	1,206	4	320 (160)	1,210
April	40 (20)	279 (139)	1 (1)	1,204	6	320 (160)	1,210
May	40 (20)	278 (139)	2 (1)	1,202	8	320 (160)	1,210
June	40 (20)	277 (138)	3 (2)	1,195	15	320 (160)	1,210
July	40 (20)	277 (138)	3 (2)	1,195	15	320 (160)	1,210
August	40 (20)	277 (138)	3 (2)	1,195	15	320 (160)	1,210
September	40 (20)	278 (139)	2 (1)	1,202	8	320 (160)	1,210
October	40 (20)	279 (139)	1 (1)	1,204	6	320 (160)	1,210
November	47 (24)	272 (136)	1 (0)	1,206	4	320 (160)	1,210
December	81 (40)	239 (120)	0 (0)	1,206	4	320 (160)	1,210

[a] Figures outside the parentheses represent pre-1996 numbers while the figures inside the parentheses represent current numbers.

[b] Only milk cows are confined.

Table 8.9. Annual fecal coliform loadings to stream and pasture by dairy and beef cattle in the subwatersheds of the Lower Big Otter River HU (L28)

Subwatershed	Stream ($\times 10^{12}$ cfu/year)		Pasture ($\times 10^{12}$ cfu/year)	
	Pre-1996	Current	Pre-1996	Current
2801	13.7	9.5	2,764	1,932
2802	12.4	12.4	1,688	1,688
2803	12.6	12.6	1,483	1,483
2804	7.7	7.7	873	873
2805	23.3	23.3	3,827	3,827
2806	15.1	15.1	3,241	3,241
2807	4.5	4.5	960	960
2808	11.1	11.1	1,327	1,327
Total	**100.4**	**96.2**	**16,163**	**15,331**

<u>Direct manure deposition on pastures</u>

When not in confinement, cattle that do not deposit fecal coliform in the stream, contribute to fecal coliform loading on the pasture. Based on the monthly confinement schedule (Table 2.8) and stream access by subwatershed (Table 8.7), the numbers of dairy and beef cattle depositing fecal coliform on pasture are presented in Table 8.8. Total fecal coliform deposition on pasture was calculated by adding the fecal coliform production by the different types of cattle defecating on the pasture. Annual fecal coliform loading on the pastures in the subwatersheds of the Lower Big Otter HU by dairy and beef cattle are given in Table 8.9.

Land application of dairy manure

A typical milk cow weighs 1,400 lb and produces 17 gallons of liquid manure per day (ASAE, 1998). Hence, annual dairy manure production in confinement was estimated at 0.32 million gallons; current production was estimated to be 0.16 million gallons/year. There is one dairy operation in subwatershed 2805; another dairy operation in subwatershed 2801 is no longer in operation. It was assumed that all dairy manure produced in confinement was applied to cropland and pasture at 8,000 and 4,000 gallons/acre-year, respectively, within the subwatershed. In subwatershed 2801, based on the pre-1996 numbers, it was estimated that 100.0 and 5.7% of cropland and pasture, respectively, received dairy manure as per the application schedule given in Table 2.10. Currently, in subwatershed 2801, there is no dairy manure available for land application. In subwatershed 2805, since the dairy herd size has remained unchanged, it is estimated that 17.6 and 1.1% of cropland and pasture, respectively, receive dairy manure. Fecal coliform in stored manure is subject to die-off (discussion on storage capacity for dairy manure is given in Section 2.6). After accounting for die-off during storage (Section 3.4), fecal coliform loadings from dairy manure to cropland and pasture in subwatersheds 2801 and 2805 are given in Table 8.10.

Table 8.10. Annual fecal coliform loadings to cropland and pasture in subwatersheds 2801 and 2805 of the Lower Big Otter River HU (L28)

Subwatershed	Cropland ($\times 10^{12}$ cfu/year)		Pasture ($\times 10^{12}$ cfu/year)	
	Pre-1996	Current	Pre-1996	Current
2801	1.1	0.0	0.6	0.0
2805	1.1	1.1	0.6	0.6

Wildlife

Based on the animal density (animals/acre-habitat) and acreage of habitat (Section 2.6), the wildlife species were distributed among the subwatersheds of the Lower Big Otter River HU (Table 8.11). Depending on the wildlife species, an animal deposits part of its waste loading directly into the stream (Table 2.11) while the remainder is deposited on land. The waste that was deposited on land was distributed among the different land use types that constituted the wildlife species habitat based on their percentages of the total habitat.

Annual distribution of fecal coliform loading from wildlife waste between the stream and different land use types is given in Table 8.12.

Table 8.11. Distribution of wildlife among the different subwatersheds of the Lower Big Otter River HU (L28)

Wildlife species	Subwatershed								Total
	2801	2802	2803	2804	2805	2806	2807	2808	
Deer	193	49	120	56	310	374	122	76	1,300
Raccoon	49	20	32	15	64	96	23	22	321
Muskrat	228	93	148	70	295	442	102	114	1,492
Beaver	24	10	16	8	31	46	11	10	156
Goose	16	4	10	5	26	32	10	6	109
Duck	7	2	5	2	12	14	5	3	50
Mallard	8	2	5	2	13	16	5	3	54
Wild Turkey	33	4	19	7	46	62	21	10	202

Table 8.12. Annual distribution of fecal coliform from wildlife among the different Land use types and streams in the subwatersheds of the Lower Big Otter River HU (L28)

Subwater-shed	Annual fecal coliform loading ($\times 10^{12}$ cfu/year)						Total
	Stream	Cropland	Forest	High Density Residential	Pasture	Rural Residential	
2801	16.4	0.0	85.1	0.2	28.1	0.7	**130.5**
2802	4.8	1.6	10.5	0.0	17.9	0.1	**34.9**
2803	10.7	0.4	53.0	0.3	18.3	0.3	**83.0**
2804	4.7	0.4	15.5	0.8	12.4	3.5	**37.3**
2805	25.9	1.4	123.1	7.5	41.1	8.6	**207.6**
2806	32.6	5.2	180.1	3.3	32.4	2.2	**255.8**
2807	10.1	10.8	53.0	0.2	6.1	1.7	**81.9**
2808	6.8	6.5	23.9	0.1	14.2	0.3	**51.8**
Total	**112**	**26.3**	**544.2**	**12.4**	**170.5**	**17.4**	**882.8**

8.2.3 Summary: Contribution from All Sources

Based on the inventory of sources discussed in Sections 8.2.2.1 through 8.2.2.4, contribution of the different nonpoint sources to direct annual fecal coliform loading to the streams for both the pre-1996 and current conditions is given in Table 8.12. Distribution of annual fecal coliform loading from nonpoint sources among the different land use categories for both the pre-1996 and current conditions are also given in Table 8.12.

From Table 8.12, it is clear that nonpoint source loadings to the land surface are nearly 120 times larger than direct nonpoint source loadings to the streams, with pastures receiving nearly 94% of the total fecal coliform load. It could be prematurely assumed that most of the fecal coliform loading in streams originates from upland sources, primarily, from pastures. However, other factors such as precipitation and proximity to streams also impact the amount of fecal coliform from upland areas that reaches the streams.

Table 8.13. Annual fecal coliform loadings to the stream and the various Land use categories in the Lower Big Otter River HU (L28)

Source	Pre-1996		Current	
	Fecal coliform loading ($\times 10^{12}$ cfu/year)	Percent of total loading	Fecal coliform loading ($\times 10^{12}$ cfu/year)	Percent of total loading
Direct loading to streams				
Cattle in stream	100.3	0.58	96.1	0.58
Wildlife in stream	40.9	0.24	40.9	0.25
Straight pipes	1.8	0.01	1.8	0.01
Loading to land surfaces				
Commercial/industrial	0.56	<0.01	0.56	<0.01
Cropland	11.83	0.07	10.71	0.06
Forest	198.60	1.15	198.60	1.21
High density residential	4.53	0.03	4.53	0.03
Pasture	16,226.5	93.89	15,394.31	93.62
Rural residential	696.26	4.03	696.26	4.23
Total	**17,281.33**	**100.0**	**16,443.66**	**100.0**

8.3 Modeling Process

8.3.1 Introduction

The Lower Big Otter River HU has a total area of 27,645 acres and is located at the outlet of the BOR basin. Most of the HU is forested or in pasture. All of the Lower Big Otter River HU drains to the impaired segment, along with the rest of the upstream BOR basin. The Lower Big Otter River is listed as impaired from its confluence with Buffalo Creek down to the confluence with the Roanoke River. The drainage area contributing to the impaired segment is 220,449 acres and includes the HUs of Flat Creek (unimpaired), Buffalo Creek (unimpaired), Little Otter River (impaired), Machine Creek (impaired), Elk Creek (impaired), North Otter Creek (unimpaired), and Sheep Creek (impaired). The VADEQ monitoring station is located near the outlet of the BOR. Since no monitored flow records are available at this station or at any other point within the Lower Big Otter River HU, the hydrology parameter set developed during the BOR basin hydrology calibration was used for Lower Big Otter River TMDL. The water quality parameters were calibrated to the observed data at the Lower Big Otter River VADEQ monitoring station.

8.3.2 Selection of Subwatersheds

The Lower Big Otter River HU was subdivided into eight subwatersheds and twelve reaches (Fig. 8.1) for modeling purposes. The subwatersheds and reaches were delineated based on the stream network, land use patterns and the presence of monitoring stations and point source discharges. A single permitted point source and water withdrawal were located in the Lower Big Otter River HU, but the quantities discharged and withdrawn were insignificant compared to even the lowest flows in the BOR and they were not simulated.

8.3.3 Input Data

The HSPF model requires a wide variety of input data to describe hydrology, water quality, and land use characteristics of the watershed. The different types and sources of input data used to develop the TMDL for the Lower Big Otter River HU are discussed below.

Climatological Data

Hourly precipitation data were obtained from the National Climatic Data Center's (NCDC) cooperative weather station at Lynchburg Municipal Airport, located approximately 10 miles to the North of the watershed. A complete set of surface meteorological data and hourly precipitation data was available for the Lynchburg station. Detailed descriptions of the weather data and the procedure for converting the raw data into the required data set is described in Appendix B.

Hydrology Model Parameters

The hydrology parameters required by PWATER and IWATER were defined for every land use category for each subwatershed. For each reach, a function table (FTABLE) is required to describe the relationship between water depth, surface area, volume, and discharge (Donigian et al., 1995). These parameters were estimated by surveying representative channel cross-sections in each subwatershed. Hydrology parameters required for the PWATER, IWATER, HYDR, and ADCALC sub-modules are listed in Appendix B.1 of BASINS ver. 2.0 User's Manual (Lahlou et al., 1998). Parameters required as inputs for

PQUAL, IQUAL, and GQUAL are given in Appendix B.1 of BASINS ver. 2.0 User's Manual (Lahlou et al., 1998). Values for the parameters were estimated based on local conditions when possible, otherwise the default parameters provided within HSPF were used. Key HSPF parameters used in the Lower Big Otter River simulations are listed in Table 8.13.

Land use

Virginia DCR identified 24 land uses in the BOR basin. As described in Chapter 2, the 24 land uses were consolidated into six categories based on hydrologic, waste application, and agricultural production characteristics (Table 2.2). The land use categories were assigned pervious/impervious percentages, which allowed a land use with both pervious and impervious fractions to be modeled using both the PERLND and IMPLND modules. Land use data were used to select several hydrology and water quality parameters for the simulations.

8.3.4 Model Calibration and Validation

The water quality component of HSPF was calibrated by comparing the simulated daily fecal coliform values with 23 fecal coliform samples collected by VADEQ between August 1992 and December 1998. The goodness of the calibration was evaluated visually using graphs of simulated and observed values. The HSPF fecal coliform parameters used in model calibration are presented in Table 8.13. Given the sparse amount of observed data, three criteria were used to assess the adequacy of the water quality calibration. The first was that the simulated concentrations were not consistently lower than the observed concentrations. This criteria assured that the simulation was not biased to lower concentrations. The second criterion was that the simulated concentrations equaled or exceeded the capped concentrations of the observed values. This assured that the simulation sufficiently represents the transport of fecal coliform during intense surface runoff events. Finally, the third criterion was that the simulated concentrations followed the same general pattern as the observed across seasons and through the years.

The Lower Big Otter River simulations depended on inflows form the upstream watersheds. The inflows from upstream watersheds were incorporated into each downstream watershed simulation using the procedures outlined in EPA Tech Note 4 (USEPA, 1999). Hourly output for stream flow and fecal coliform loads were used as MUTSIN input to the downstream watershed. The order of the simulations and the inflows of the watershed contributing to the

Lower Big Otter River HU are shown in Figure 8.1. The calibrations for Sheep Creek, Elk Creek, Little Otter River, and Machine Creek are discussed in Section 3 of Chapters 4, 5, 6, and 7, respectively. Calibration was conducted for North Otter Creek, Buffalo Creek, and Flat Creek watersheds using the VADEQ monitoring stations 4ABNF001.06, 4ABOR016.26, and 4AFCA001.40, respectively. The calibrated model output for North Otter Creek, Buffalo Creek, and Flat Creek HUs are shown in Figures 8.5, 8.6, and 8.7, respectively. In the final simulation of the Lower Big Otter River HU, the inflows to the Lower Big Otter River HU from Flat Creek and Buffalo Creek were simulated as times series MUTSIN file inputs of hourly flow rate and fecal coliform loading.

The calibrated model output at VADEQ station 4ABOR000.62 is shown with the observed data in Figure 8.8. The goodness of the calibration was evaluated visually using the simulated and observed values in Figure 8.8. The initial water quality parameters selected for the Lower Big Otter River HU were adequate with the exception of the PLS wash-off factor (WSQOP), which was changed to 2.4 in/hr in the Lower Big Otter River HU. The pervious surface wash-off parameter was 1.8 in/hr in all other watersheds except Sheep and Elk Creeks, where it was 1.0 and 2.4 in/hr, respectively. Other water quality parameters were the same as those used in the other watersheds. The HSPF fecal coliform parameters used in model calibration are summarized in Table 8.13. As shown in Figures 8.5 to 8.8, the calibrated HSPF water quality parameters fit the observed data for the existing conditions well for Elk Creek, Flat Creek, Buffalo Creek, and the Lower Big Otter River, respectively. The fecal coliform concentrations predicted by the model represent both the low and high observed values and exceed the 8000 cfu/100mL "capped" observed values as required. The calibrated predicted concentrations also followed the same general pattern as the observed data across seasons and through the years. In light of the limited data available for calibration and validation, and to the degree that both the trends and range of the observed data are reflected by the model predictions, the calibrated parameter set appears reasonable for representing the watershed and for TMDL development purposes.

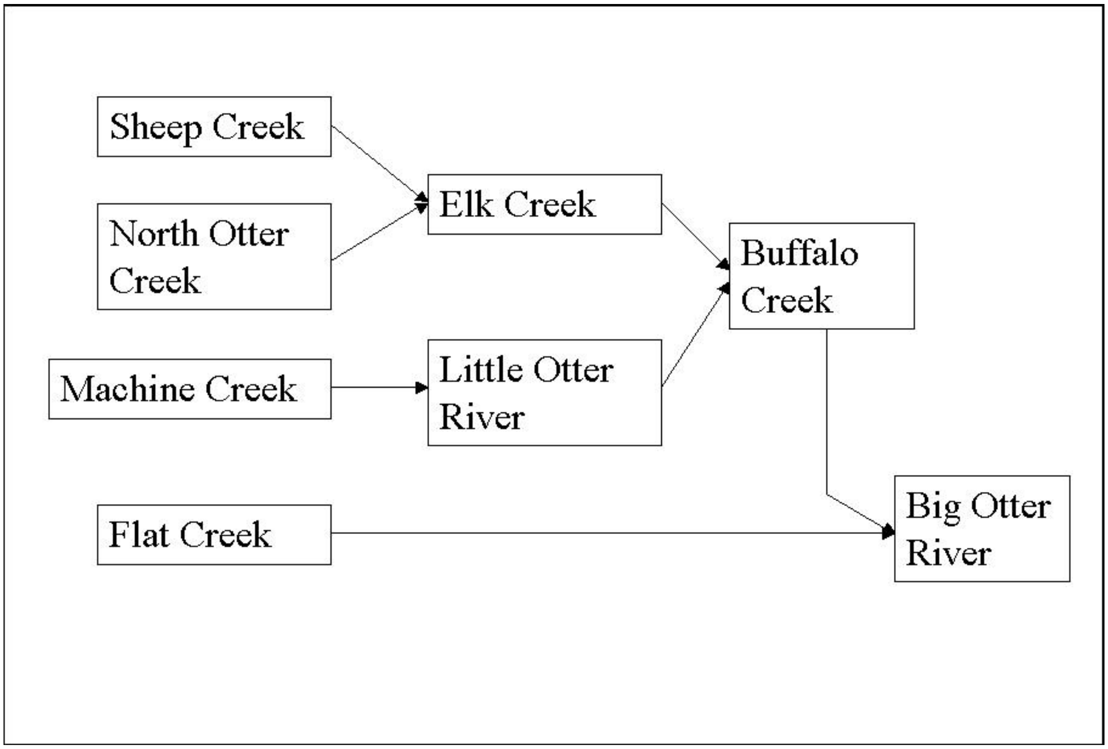

Figure 8.4. Inflows for the Lower Big Otter River Simulations

Table 8.14. Input parameters used in HSPF simulations for the Lower Big Otter River HU (L28).

			RANGE OF VALVES						
PARAMETER	DEFINITION	UNITS	TYPICAL		POSSIBLE		START	FINAL	FUNCTION OF…
PERLIND			MIN	MAX	MIN	MAX		CALIB.	
PWAT-PARM2									
FOREST	Fraction forest cover	none	0.00	0.5	0	0.95	0.0, 1.0	1.0 forest, 0.0 other	Forest cover
LZSN	Lower zone nominal soil moisture storage	inches	3	8	2	15	14.1	4.5-11.3[1]	Soil properties
INFILT	Index to infiltration capacity	in/hr	0.01	0.25	0.001	0.5	0.16	0.054-0.086[1]	Soil and cover conditions
LSUR	Length of overland flow	feet	200	500	100	700	300	300	Topography
SLSUR	Slope of overland flowplane	none	0.01	0.15	0.001	0.3	0.035	0.05	Topography
KVARY	Groundwater recession variable	1/in	0	3	0	5	0	0	Calibrate
AGWRC	Base groundwater recession	none	0.92	0.99	0.85	0.999	0.98	0.97	Calibrate
PWAT-PARM3									
PETMAX	Temp below which ET is reduced	deg. F	35	45	32	48	40	40	Climate, vegetation
PETMIN	Temp below which ET is set to zero	deg. F	30	35	30	40	35	35	Climate, vegetation
INFEXP	Exponent in infiltration equation	none	2	2	1	3	2	2	Soil properties
INFILD	Ratio of max/mean infiltration capacities	none	2	2	1	3	2	2	Soil properties
DEEPFR	Fraction of GW inflow to deep recharge	none	0	0.2	0	0.5	0.1	0	Geology
BASETP	Fraction of remaining ET from baseflow	none	0	0.05	0	0.2	0.02	0.0-0.02[1]	Riparian vegetation
AGWETP	Fraction of remaining ET from active GW	none	0	0.05	0	0.2	0	0	Marsh/wetlands ET
PWAT-PARM4									
CEPSC	Interception storage capacity	inches	0.03	0.2	0.01	0.4	0.1	monthly[1]	Vegetation
UZSN	Upper zone nominal soil moisture storage	inches	0.10	1	0.05	2	1.128	0.235-2.05[1]	Soil properties
NSUR	Mannings' n (roughness)	none	0.15	0.35	0.1	0.5	0.2	0.06-0.09[1]	Landuse, surface condition
INTFW	Interflow/surface runoff partition parameter	none	1	3	1	10	0.75	1.4	Soils, topography, land use
IRC	Interfiow recession parameter	none	0.5	0.7	0.3	0.85	0.5	0.3	Soils, topography, land use
LZETP	Lower zone ET parameter	none	0.2	0.7	0.1	0.9	monthly	monthly[1]	Vegetation
QUAL-INPUT									
ACQOP	Rate of accumulation of constituent	#/day						monthly[1]	Land use
SQOLIM	Maximum accumulation of constituent	#						9 x ACQOP	Land use
WSQOP	Wash-off rate	in/hr						2.4	Land use
IOQC	Constituent conc. in interflow	$\#/ft^3$						2832	Land use

[1] Varies with land use

Table 8.14. Input parameters used in HSPF simulations for the Lower Big Otter River (Continued).

			RANGE OF VALVES						
PARAMETER	**DEFINITION**	**UNITS**	**TYPICAL**		**POSSIBLE**		**START**	**FINAL**	**FUNCTION OF…**
PERLIND			**MIN**	**MAX**	**MIN**	**MAX**		**CALIB.**	
AOQC	Constituent conc. in active groundwater	$\#/ft^3$						1416	Land use
IMPLND									
IWAT-PARM2									
LSUR	Length of overland flow	feet	200	500	100	700	300	300	Topography
SLSUR	Slope of overland flowplane	none	0.01	0.15	0.001	0.3	0.035	0.01	Topography
NSUR	Mannings' n (roughness)	none	0.15	0.35	0.1	0.5	0.2	0.05	Land use, surface condition
RETSC	Retention/interception storage capacity	inches	0.03	0.2	0.01	0.4	0.1	0.065	Land use, surface condition
IWAT-PARM3									
PETMAX	Temp below which ET is reduced	deg. F	35	45	32	48	40	40	Climate, vegetation
PETMIN	Temp below which ET is set to zero	deg. F	30	35	30	40	35	35	Climate, vegetation
IQUAL									
ACQOP	Rate of accumulation of constituent	#/day						1.00E+07	Land use
SQOLIM	Maximum accumulation of constituent	#						3.00E+07	Land use
WSQOP	Wash-off rate	in/hr						1.8	Land use
RCHRES									
HYDR-PARM2									
KS	Weighting factor for hydraulic routing							0.25	
GQUAL									
FSTDEC	First order decay rate of the constituent	1/day						1.15	
THFST	Temperature correction coeff. for FSTDEC							1.05	

[1] Varies with land use

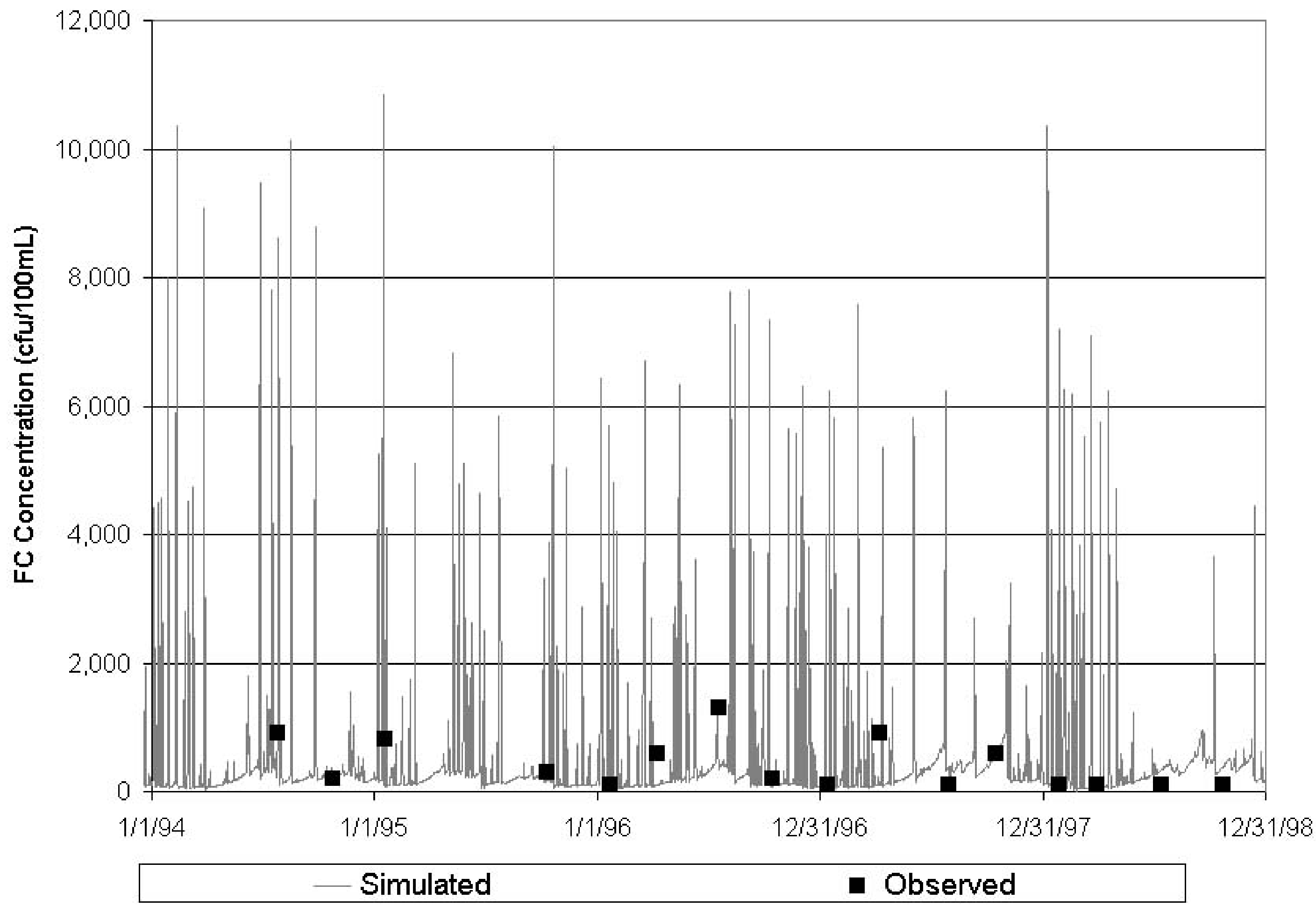

Figure 8.5. Simulated and observed fecal coliform concentrations for North Otter Creek.

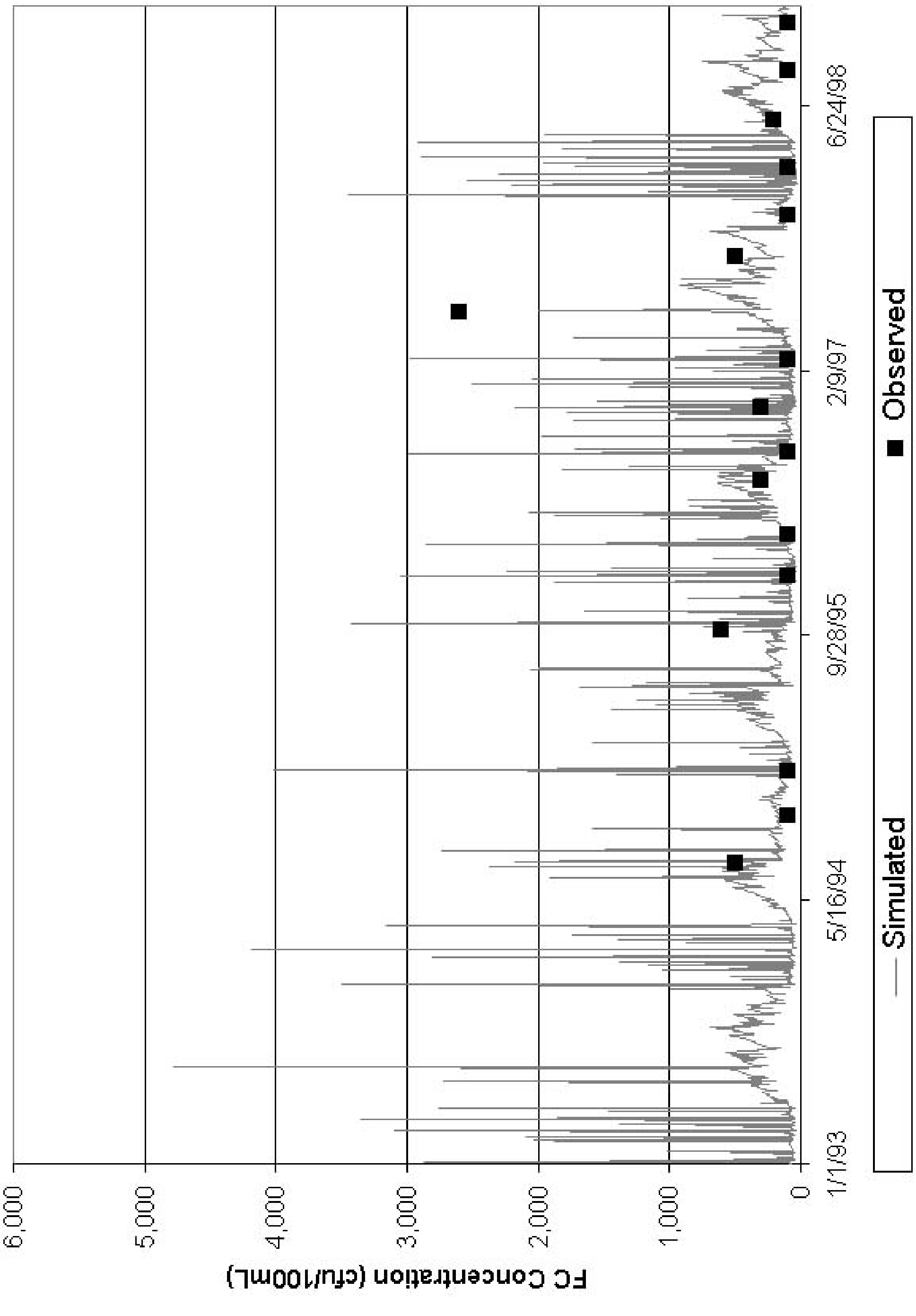

Figure 8.6. Simulated and observed fecal coliform concentrations for Flat Creek.

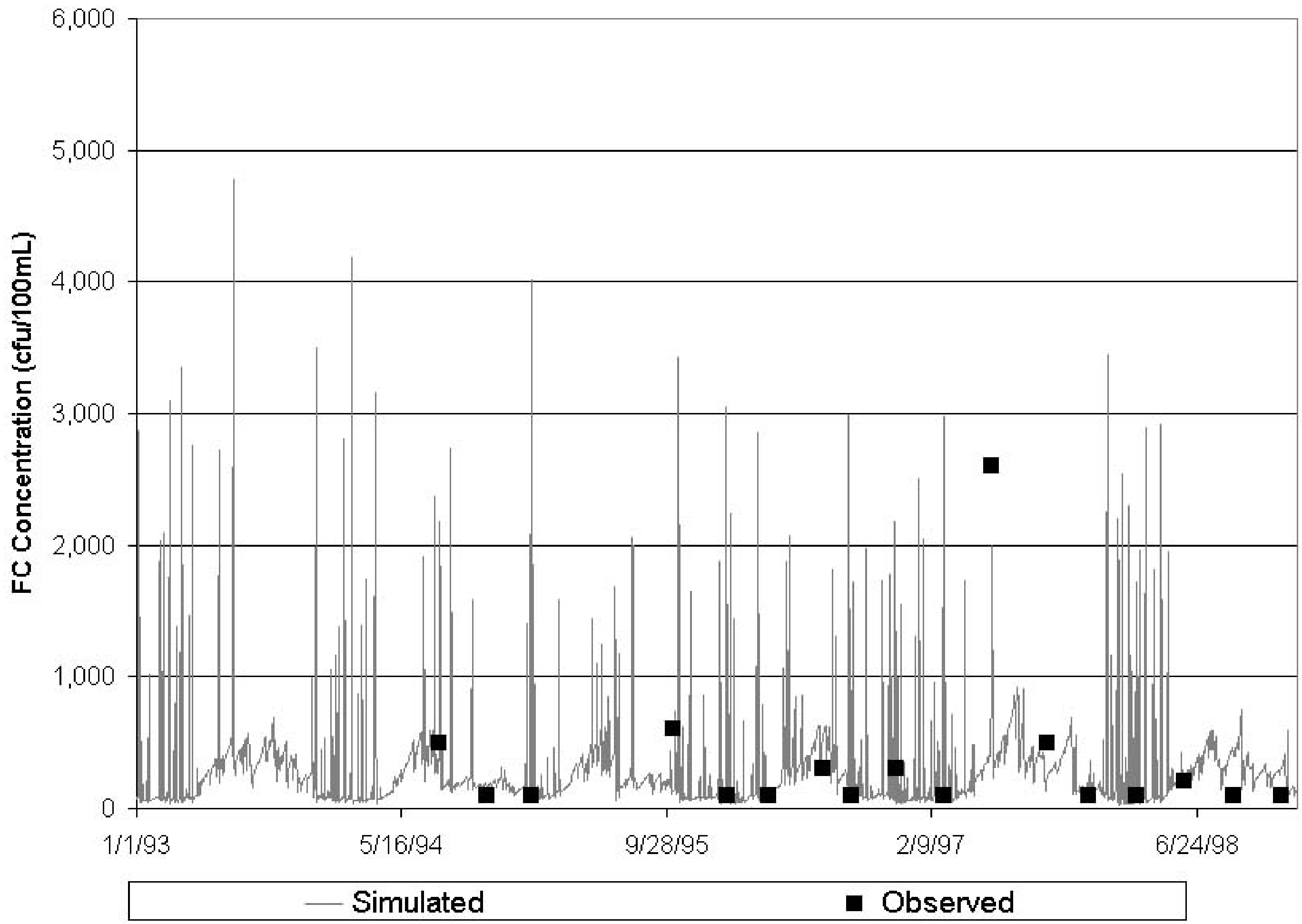

Figure 8.7. Simulated and observed fecal coliform concentrations for Buffalo Creek.

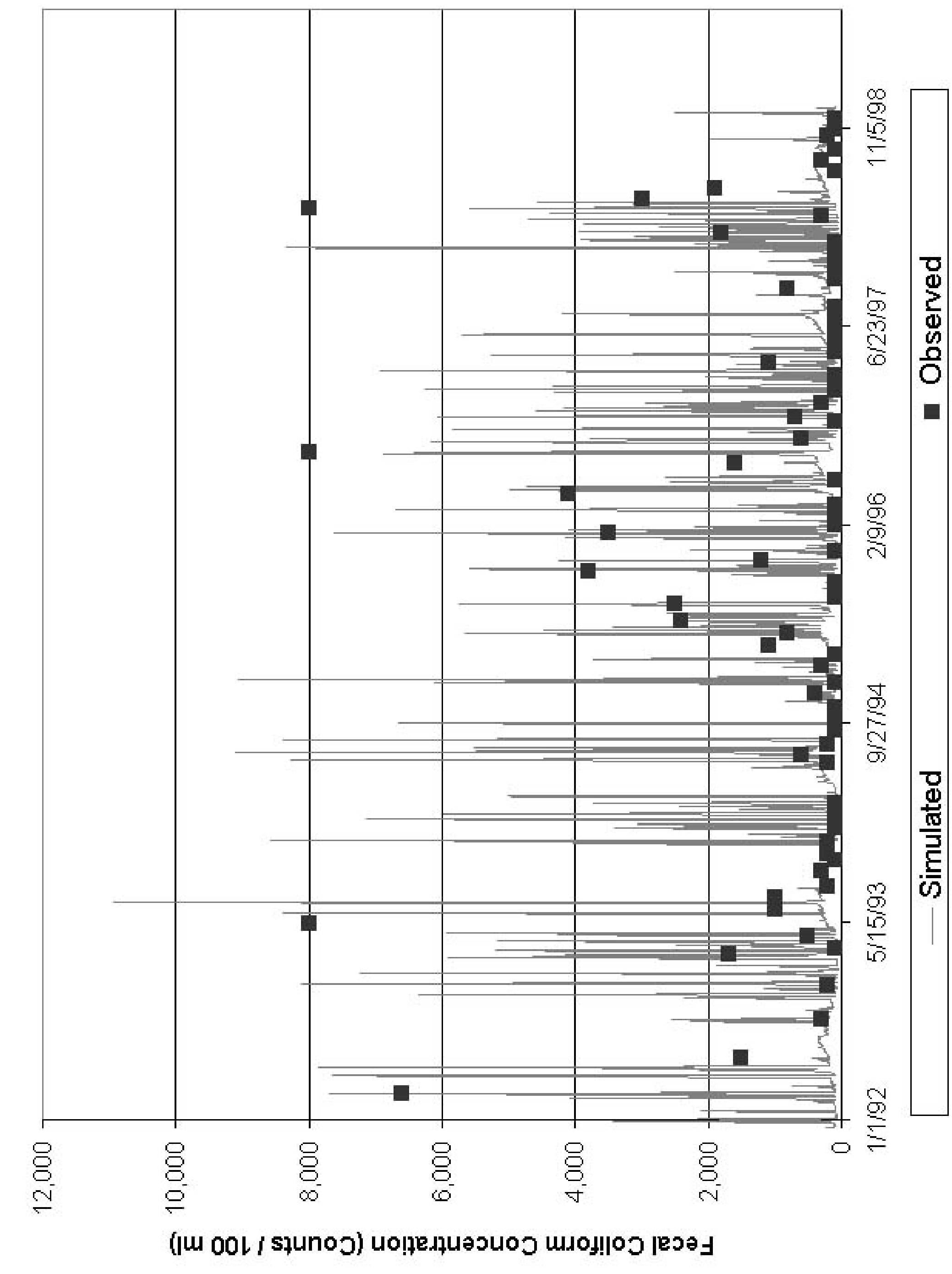

Figure 8.8. Simulated and observed fecal coliform concentrations for the Lower Big Otter River.

8.4 Load Allocations

8.4.1 Background

The objective of a TMDL is to allocate allowable loads among different pollutant sources so that the appropriate control actions can be taken to achieve water quality standards (USEPA, 1991). The objective of the TMDL for the Lower Big Otter River HU is to determine what reductions in fecal coliform loadings from point and nonpoint sources are required to meet state water quality standards. The Lower Big Otter River HU is the outlet watershed of the BOR basin, and therefore, receives pollutants from all the upstream watersheds, including three watersheds that are not listed as impaired segments (North Otter Creek, Buffalo Creek, and Flat Creek). The Big Otter River is listed as impaired for the entirety of its length in the Lower Big Otter River HU; thus, all subwatersheds defined in the Lower Big Otter River HU were considered to contribute to the impairment. The TMDL was developed for the outlet reach of the Lower Big Otter River HU.

The state water quality standard for fecal coliform used in the development of the TMDL was the 30-day geometric mean standard of 200 cfu/100mL. The TMDL considers all sources contributing fecal coliform to the BOR. The sources can be separated into nonpoint and point (or direct) sources. The incorporation of the different sources into the TMDL are defined in the equation:

$$TMDL = WLA + LA + MOS \qquad [8.1]$$

where,

WLA	=	waste load allocation (point source contributions);
LA	=	load allocation (nonpoint source contributions); and
MOS	=	Margin of safety.

A MOS is included to account for uncertainty in the TMDL development process. There are several ways that the MOS can be incorporated into the TMDL (USEPA, 1991). For the Lower Big Otter River TMDL, a margin of safety of 5% (i.e. MOS = 10 cfu/100mL) was used. By subtracting the MOS from the TMDL standard of 200 cfu/100mL, the goal of the TMDL allocation was that the combined point source (WLA) and nonpoint source (LA) loads be below the target fecal coliform concentration (30-day geometric mean) of 190 cfu/100mL..

The time period selected for the calibration and load allocation study was January 1, 1993 to December 31, 1998 because this period incorporates a wide range of hydrologic events including both low and high flow conditions. This is also a period in which observed data were available.

8.4.2 Calibration Period and Existing Conditions

Analysis of the simulation results for the calibration period (Table 8.14) shows that fecal coliform loads due to inflow from Buffalo Creek are the major source fecal coliform loading to the Lower Big Otter River HU, accounting for about 67% of the total mean daily fecal coliform concentration. In contrast, inflow from Flat Creek contributes only about 4% of the total mean daily fecal coliform concentration. Loads from PLS in the Lower Big Otter River HU on average contribute about 24% of the mean daily fecal coliform concentration. The loads from the direct deposition by cattle and wildlife are responsible for an average of about 3% and 1%, respectively.

Table 8.15. Relative contributions of different fecal coliform sources to the overall mean fecal coliform concentration for the calibration period.

Fecal Coliform Source	Mean Daily Fecal Coliform Concentration Attributable to Sources, cfu/100mL	Relative Contribution by Source %
Baseline -- All Sources	739	100
Direct Deposit from Cattle Only	25	3.4
Direct Deposit from Wildlife Only	10	1.4
Straight Pipe Discharge Only	0	0.0
Loads from PLS Only	180	24.4
Loads from ILS Only	0	0.0
Contribution from Interflow and Groundwater	0	0.0
Contribution from Buffalo Creek Inflow	494	66.8
Contribution from Flat Creek Inflow	30	4.1

The simulation of existing conditions provides the baseline for evaluating reductions required for the TMDL allocation. Cattle populations were reduced for the existing condition simulations, compared to the calibration period. The cattle population during the calibration period represented the average cattle populations in the watersheds from 1993 to 1998. The existing condition cattle populations account for the known decreases in dairy cattle populations during the last three to four years. Fecal coliform loads (NPS and direct NPS) used in the development of the TMDL allocation represent the cattle populations for "existing conditions". The calibrated hydrology and water quality parameter sets along with the best estimate of fecal coliform loads in the watershed were then used to simulate daily fecal coliform concentrations for the selected allocation study period of Jan 1, 1993 to Dec 31, 1998.

Table 8.15 gives the concentrations of fecal coliform from direct NPS for the calibration period conditions. Simulated 30-day mean fecal coliform concentrations in the Lower Big Otter River during the calibration period are shown in Figure 8.9 along with the geometric mean standard. Simulated concentrations are generally above the geometric mean standard. The concentration of fecal coliform is higher during the summer months due to reduced dilution during low-flow conditions.

Table 8.16. Fecal coliform loads for the Lower Big Otter River from direct nonpoint sources.

Source	Fecal coliform loads ($\times 10^{12}$ cfu/year)	Percent of total loading
Cattle in stream	96.1	69.2
Wildlife in stream	40.9	29.5
Straight pipes	1.8	1.3
Total	**138.8**	**100.0**

Despite their small contribution to the mean daily concentration, direct deposits by cattle may be a critical source within the Lower Big Otter River HU, especially during the summer, when increased time spent in the water corresponds with the decreased dilution associated with low stream flow. In summer months, it is estimated that cattle spend two hours per day in water (Table 2.8). Hence, of the 669 cattle on pastures with stream access, an equivalent of 56 cattle spend the entire day in the stream. It is estimated that 30% of the feces of these cattle is deposited in the water, which is the equivalent of the waste from 17 cattle being directly deposited in the stream. This accounts for 2.5% of the entire manure load produced by cattle on pastures with stream access. The fraction of manure directly deposited in the stream at other times of the year is lower, but can still contribute to water quality standard exceedances during low-flow periods.

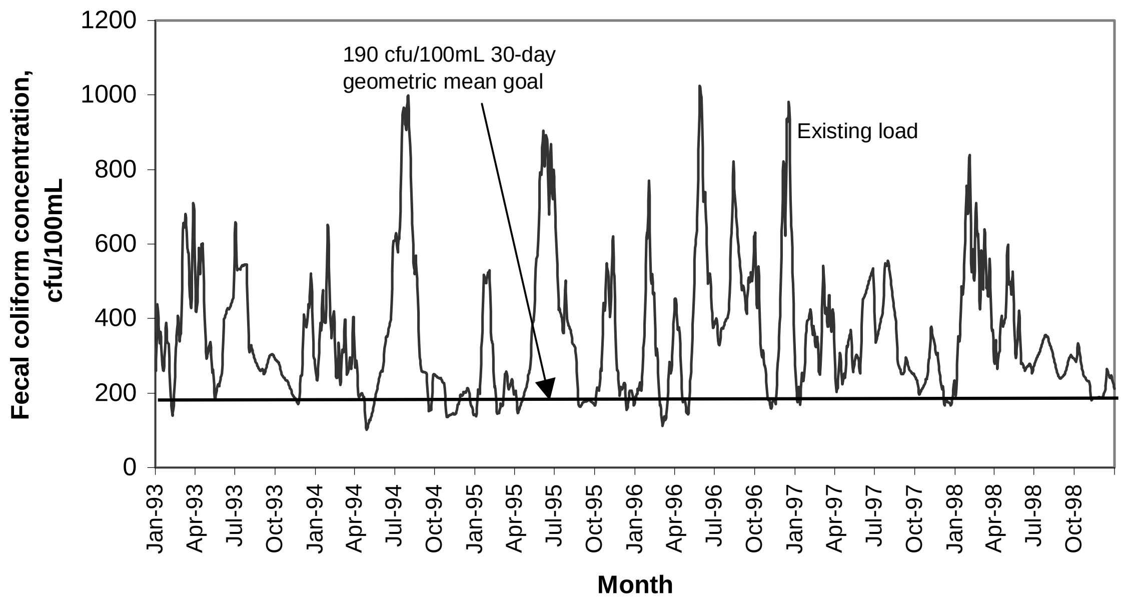

Figure 8.9. Simulated 30-day mean fecal coliform concentrations in the Lower Big Otter River (at the outlet of the watershed) due to existing fecal coliform loads.

8.4.3 Allocation Scenarios

Several allocation scenarios were evaluated, and as shown in Table 8.16, only the most restrictive scenario (5) meets the TMDL allocation requirement of zero violations of the 190 cfu/100mL 30-day geometric mean standard. Loads from straight pipes were reduced by 100% for all scenarios. In addition to those reductions, direct deposition from cattle was reduced by 80% in scenario 1 and by 100% in all the other scenarios. Even completely eliminating the contribution from straight pipes and direct deposition of cattle into streams (100% reduction) did not achieve the 190 cfu/100mL 30-day geometric mean standard. Therefore, reductions were made in direct wildlife deposits and NPS from agricultural land segments as indicated in Table 8.16. Reducing fecal coliform contributions from sources only within the Lower Big Otter River HU was not sufficient to meet the standards. Additional reductions were required from other watersheds inside the BOR basin that were not listed as impaired (North Otter Creek, Buffalo Creek, and Flat Creek). The previously mentioned reductions inside the Lower Big Otter River HU (scenario 5 in Table 8.16) were combined with the upstream watershed reductions indicated in Table 8.17 to meet the TMDL goal for the Lower Big Otter River.

Table 8.17. Fecal coliform TMDL allocation scenarios for the Lower Big Otter River

Scenario	Percent Reduction in Direct Deposit from Cattle	Percent Reduction in Direct Deposit from Wildlife	Percent Reduction in Straight Pipes	Loads from Agricultural Land Segments	Percent Exceedances of 190 cfu/100 mL Geometric Mean Standard
1	80	0	100	0	16.5
2	100	0	100	0	14.0
3	100	50	100	0	11.6
4[1]	100	50	100	50	0.6
5 [2]	**100**	**50**	**100**	**50**	**0.0**
6 [2]	100	30	100	40	0.9
7 [2]	100	50	100	30	0.7

[1] Reduction of 25% for upstream loads from Buffalo Creek

[2] Reduction of 30% for upstream loads from Buffalo Creek achieved with the reductions shown in Table 8.17

TMDL allocation plan in bold

Table 8.18. Required reductions in unimpaired upstream watersheds for the Lower Big Otter River TMDL allocation plan*

Scenario	Percent Reduction in Direct Deposit from Cattle	Percent Reduction in Direct Deposits from Wildlife	Percent Reduction in Straight Pipes	NPS Loads from Agricultural Land Segments
North Otter Creek	100	50	100	50
Buffalo Creek	100	50	100	50
Flat Creek	0	0	100	0

* All other watersheds with impaired segments have TMDL allocation plans with reductions applied throughout the DCR watershed

Table 8.18 shows the NPS loads for all pervious land uses and the results of the 50% NPS reduction from agricultural land segments (cropland and pasture) required by the TMDL allocation scenario (scenario 5 in Table 8.16). It must be noted that even though the Buffalo Creek, North Otter Creek, and Flat Creek watersheds were not listed as being impaired the outflow from these watersheds may still cause violations of the geometric mean standard of the downstream watershed (Lower Big Otter River). Waters of the Commonwealth are listed as being impaired from fecal coliforms if they violate the 1000cfu/100 mL instantaneous standard 10% of the time, but the TMDL plan requires that the 30-day geometric mean concentration of 190cfu/100mL not be violated at any time. Therefore, the streams in a watershed could have fecal coliform concentrations that do not exceed the instantaneous fecal coliform standard and not be listed as impaired, but consistently violate the geometric mean standard. For instance, if the fecal coliform concentration for a stream were a constant 250cfu/100mL, the 1000cfu/100mL instantaneous standard would never be violated and the stream would not be listed as impaired. However, the waters of such stream would violate the 30-day geometric mean standard 100% of the time. The reductions in direct NPS loads required by the TMDL allocation scenario are shown in Table 8.19. The graph of 30-day geometric mean fecal coliform concentrations for existing conditions and for the TMDL allocation scenario (Figure 8.10) shows that simulated concentrations do not exceed the geometric mean goal of 190 cfu/100mL during the allocation period.

Table 8.19. Annual NPS loads to the Lower Big Otter River for existing conditions and corresponding reductions for the TMDL allocation plan (scenario 5).

Pervious Land Segment Category	Existing Conditions		Allocation Scenario	
	Load (x 10^{12} cfu)	Percent of total load to stream from PLS	TMDL NPS allocation load (x 10^{12} cfu)	Percent reduction from existing load
Commercial/Industrial	0.01	< 0.1	0.01	0
Cropland	0.17	< 0.1	0.08	50
Forest	86.26	4.1	86.26	0
High Density Residential	0.55	< 0.1	0.55	0
Pasture	1,998.26	94.4	999.13	50
Rural Residential	31.54	1.5	31.54	0
Total	**2,116.78**	**100.0**	**1,117.57**	**47.2**

Table 8.20. Annual direct NPS loads to the Lower Big Otter River for existing conditions and required reductions for the TMDL allocation plan (scenario 5).

Source	Existing Conditions		TMDL Allocation Plan	
	Fecal coliform load ($\times 10^{12}$ cfu/year)	Percent of total load to stream from direct NPS	NPS allocation load* ($\times 10^{12}$ cfu/year)	Percent reduction
Cattle in streams	96.1	69.2	0.0	100.0
Wildlife in streams	40.9	29.5	20.5	50.0
Straight pipes	1.8	1.3	0.00	100.0
Total	**138.8**	**100.0**	**20.5**	**85.2**

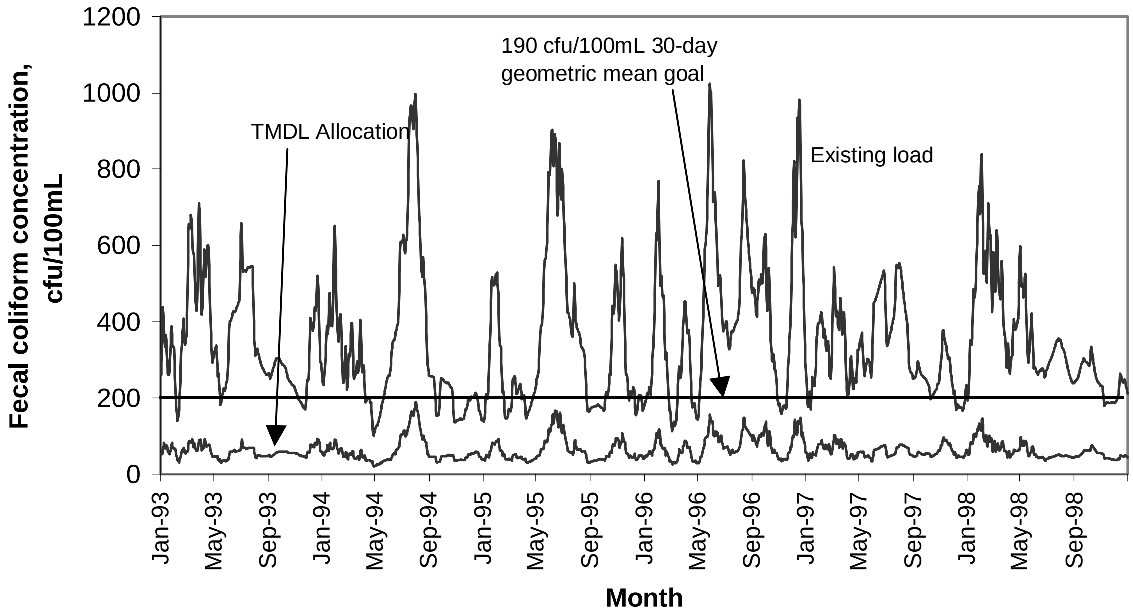

Figure 8.10. Predicted 30-day geometric mean fecal coliform concentrations for the Lower Big Otter River (at the HU outlet) for existing conditions and for the TMDL allocation plan.

8.4.4 Summary of TMDL Allocation

A TMDL for fecal coliform has been developed for the Lower Big Otter River HU. The TMDL addresses the following issues.

1 The TMDL meets the water quality standard of no exceedances of the 30-day geometric mean fecal coliform concentration of 200 cfu/100 mL..

2 A MOS of 5% was incorporated in the development of the TMDL plan.

3 The TMDL accounts for fecal coliform from human, domestic/agricultural animals, and wildlife sources.

4 Both high and low-flow stream conditions were considered in developing the TMDL. Low flow conditions were found to be the environmental condition most likely to cause a violation of the 30-day geometric mean.

5 Both the flow regime and fecal coliform loadings are seasonal, with higher loadings and in-stream concentrations during the summer than in the winter. The TMDL accounts for these seasonal effects.

6 A TMDL allocation plan to meet the 30-day geometric mean water quality goal of 190 cfu/100mL requires: a 100% reduction in direct deposits of cattle manure to streams in the Lower Big Otter River watershed, Buffalo Creek, and North Otter River watersheds; a 50% reduction in direct deposits by wildlife to streams in the Lower Big Otter River HU, Buffalo Creek, and North Otter River watersheds; a 50% reduction in NPS loadings from pasture and cropland in the Lower Big Otter River HU, Buffalo Creek, and North Otter Creek watersheds; and elimination of all direct pipes in all subwatersheds including the Flat Creek watershed. A summary of the fecal coliform TMDL allocation plan loads for the Lower Big Otter River is presented in Table 8.21.

Table 8.21. The Lower Big Otter River TMDL allocation plan loads (cfu/year).

Subwatershed	Point Source Loads	Nonpoint Source Loads[a]	Margin of Safety[b]	TMDL Annual Load
Big Otter River	<$0.1 X10^{12}$	$1,138.1 X10^{12}$	$59.9 X10^{12}$	$1,198.0 X10^{12}$

[a] includes upstream inflows from Buffalo Creek ($2161.6 X10^{12}$ cfu/year) and Flat Creek ($3629.9 X10^{12}$ cfu/year)

[b] Five percent of TMDL

9 IMPLEMENTATION

9.1 TMDL Implementation Process

The goal of this TMDL is to develop a plan that will lead to expeditious attainment of the water quality standards. The first step in this process was to develop an implementable TMDL. The second step is to develop a TMDL implementation plan, and the final step is to implement the TMDL. Watershed stakeholders will have opportunities to provide input and to participate in development of the implementation plan, with support from regional and local offices of VADEQ, VADCR, VDH, and other participating assistance agencies.

Section 303(d) of the Clean Water Act and USEPA's 303(d) regulation (USEPA, 1998a) do not specify implementation mechanisms for TMDLs. However, Virginia's 1997 Water Quality Monitoring, Information, and Restoration Act directs VADEQ to develop a plan for the expeditious implementation of TMDLs.

VADEQ plans to incorporate TMDL implementation plans as part of the 303(e) Water Quality Management Plans (WQMP). In response to the recent USEPA/VADEQ/VADCR Memorandum of Understanding, VADEQ submitted a Continuous Planning Process to USEPA in which Virginia commits to updating the WQMP, which will be the repository of TMDLs and the implementation plans. Each implementation plan will contain a reasonable assurance section that details the availability of funds for implementation of voluntary actions.

One potential source of funding for TMDL implementation is Section 319 of the Clean Water Act. In response to the federal Clean Water Action Plan, Virginia developed a Unified Watershed Assessment that identifies watershed priorities. Watershed restoration activities, such as TMDL implementation, within these priority watersheds are eligible for Section 319 funding. Increases in Section 319 funding in future years will be targeted towards TMDL implementation and watershed restoration.

9.2 Phased Implementation and Follow-Up Monitoring

In order to avoid over-implementation, in case the model was overly conservative or the applicable water quality standard changes, implementation of best management practices (BMPs) in the watersheds should occur in phases. The benefit of phased implementation is that as stream monitoring continues, accurate measurements of progress being achieved will be recorded. This approach provides a measure of quality control, given the uncertainties that exist in the developed TMDL model.

VADEQ will continue sampling at the established monitoring stations in order to evaluate reductions in fecal bacteria counts and the effectiveness of the TMDL in attainment of water quality standards. During Phase 1 of the TMDL implementation plan, sampling for fecal coliform bacteria will continue until the violation rate of Virginia's instantaneous fecal coliform standard of 1,000 cfu/100 mL, is reduced to 10% or less. If the Phase 1 implementation plan fails to achieve the desired reductions within a reasonable period of time, additional reductions will be implemented to achieve the desired Phase 1 reductions. After the Phase 1 reduction in the fecal coliform violation rate is verified, subsequent phases of the TMDL implementation plan will begin and the monitoring frequency for fecal coliform bacteria will increase in order to provide the water quality data for evaluation and verification that the TMDL will attain and maintain Virginia's geometric mean water quality standard of 200 cfu/100 mL.

9.3 Phase 1 Implementation Scenario

The goal of the Phase 1 Implementation Scenario was to determine the fecal coliform loading reductions required to reduce violations of the instantaneous 1,000 cfu/100 mL water quality standard to 10 percent or less. The following sections describe the Phase 1 Implementation Scenarios for each impaired segment in the BOR Basin.

9.3.1 Sheep Creek Watershed

Six loadings reduction scenarios from Sheep Creek were considered. As shown in Table 9.1, Scenarios 3, 4, 5 and 6 meet the Phase 1 implementation plan goal of 10% or less violation of the 1,000 cfu/100 mL instantaneous standard. The final scenario selected for Phase 1 implementation, Scenario 6, allows some access to streams by cattle and requires a reasonable reduction in loads from pervious land surfaces. Fecal coliform concentrations resulting from Scenario 6 implementation are presented graphically in Figure 9.1. The loadings to the impaired segments in subwatersheds (2301 and 2302) for the existing conditions and Phase 1 allocation scenario for nonpoint and direct nonpoint sources are presented in Tables 9.2 and 9.3, respectively.

Table 9.1. Phase 1 implementation scenarios for Sheep Creek watershed (L23)

Scenario	Percent Reduction in Direct Deposit from Cattle	Percent Reduction in Direct Deposit from Wildlife	Percent Reduction in Straight Pipes	Percent Reduction from Pervious Agricultural Land Surfaces	Percent Exceedances of 1000 cfu/100 mL Standard
1	95	75	100	0	11.1
2	100	75	100	50	10.9
3	100	80	100	60	7.8
4	95	75	100	60	7.9
5	90	75	100	50	8.6
6[a]	**95**	**0**	**100**	**30**	**9.0**

[a] Recommended implementation scenario

Table 9.2. Annual nonpoint source fecal coliform loading reductions for Phase 1 TMDL implementation of Scenario 6 in the Sheep Creek watershed (L23)[a]

Land use Category	Existing Conditions		Implementation Scenario	
	Existing load (x 10^{12} cfu)	Percent of total load to stream from nonpoint sources	TMDL nonpoint source allocation load (x 10^{12} cfu)	Percent reduction from existing load
Commercial/Industrial	<0.01	< 0.1	<0.01	0
Cropland	1.07	< 0.1	0.75	30.0
Forest	35.68	0.9	38.29	0
High Density Residential	0.03	< 0.1	0.03	0
Pasture	4,112.79	98.9	2,878.95	30.0
Rural Residential	9.99	0.2	10.65	0
Total	**4,159.56**	**100.0**	**2,928.67**	**29.6**

[a] Only impaired subwatersheds (2301 and 2302)

Table 9.3. Annual direct nonpoint source fecal coliform loading reductions for Phase 1 TMDL implementation of Scenario 6 in the Sheep Creek watershed (L23)[a]

Source	Existing Conditions		Implementation Scenario	
	Fecal coliform loading ($\times 10^{12}$ cfu/year)	Percent of total loading	Nonpoint source ($\times 10^{12}$ cfu/year)	Percent reduction from existing loads
Cattle in stream	96.3	77.2	4.8	95.0
Wildlife in stream	19.6	15.7	19.6	100
Straight pipes	8.9	7.1	0.0	0
Total	**124.8**	**100.0**	**24.4**	**80.4**

[a] Only impaired subwatersheds (2301 and 2302)

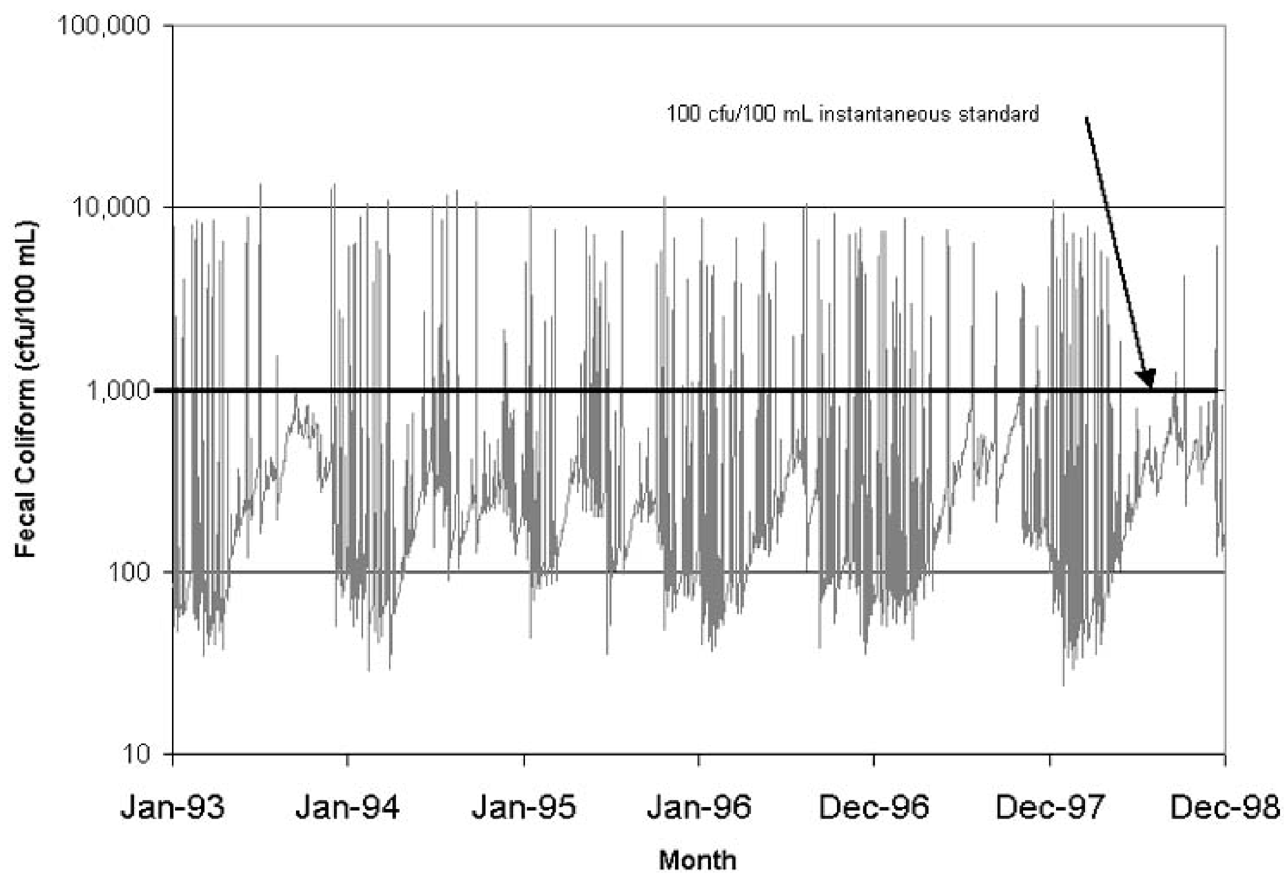

Figure 9.1. Phase 1 TMDL implementation scenario for Sheep Creek

9.3.2 Elk Creek Watershed

Six loadings reduction scenarios from Elk Creek were considered. As shown in Table 9.4, Scenarios 2,4, and 6 meet the Phase 1 implementation goal of 10% or less violation of the 1,000 cfu/100 mL instantaneous standard. The final scenario selected for Phase 1 implementation, scenario 6, allows for limited access to the stream by cattle. Furthermore, no reductions in loads from pervious surfaces are needed to meet the Phase 1 implementation goals. Fecal coliform concentrations resulting from Scenario 6 implementation are presented graphically in Figure 9.2. Loadings from the subwatersheds (2507 and 2508) that drain into the impaired segments within the Elk Creek watershed, as well as the loadings from other subwatersheds (2502 and 2503) for both the existing allocation and Phase 1 allocation scenario for nonpoint and direct nonpoint sources, respectively, are presented in Tables 9.4 and 9.5.

Table 9.4. Phase I implementation scenarios for Elk Creek watershed (L25)

Scenario	Percent Reduction in Direct Deposit from Cattle	Percent Reduction in Direct Deposit from Wildlife	Percent Reduction in Straight Pipes	Percent Reduction from Pervious Land Surfaces	Percent Exceedances of 1000 cfu/100 mL Standard
1	40	0	100	10	11.8
2	50	0	100	25	9.9
3	40	20	100	0	11.3
4	50	50	100	0	9.9
5	50	0	100	0	10.9
6[a]	**63**	**0**	**100**	**0**	**9.7**

[a] Recommended implementation scenario

Table 9.5. Annual nonpoint source fecal coliform loading reductions for Phase 1 TMDL implementation of Scenario 4 in the Elk Creek watershed (L25)[a]

Land use Category	Existing Conditions		Implementation Scenario	
	Existing load ($x\ 10^{12}$ cfu)	Percent of total load to stream from nonpoint sources	TMDL nonpoint source allocation load ($x\ 10^{12}$ cfu)	Percent reduction from existing load
Commercial/Industrial	0.01	< 0.1	0.01	0.0
Cropland	0.06	< 0.1	0.06	0.0
Forest	19.19	0.3	19.19	0.0
High Density Residential	0.39	< 0.1	0.39	0.0
Pasture	5,697.95	97.8	5,697.95	0.0
Rural Residential	106.71	1.8	106.71	0.0
Total	**5,824.31**	**100.0**	**5,824.31**	**0.0**

[a] Only impaired subwatersheds (2507 and 2308) and unimpaired subwatersheds (2502 and 2503) upstream of impaired subwatersheds

Table 9.6. Annual direct nonpoint source fecal coliform loading reductions for Phase 1 TMDL implementation of Scenario 4 in the Elk Creek watershed (L25)[a]

Source	Existing Conditions		Implementation Scenario	
	Fecal coliform loading ($\times 10^{12}$ cfu/year)	Percent of total loading	Nonpoint source ($\times 10^{12}$ cfu/year)	Percent reduction from existing loads
Cattle in stream	138.8	77.0	51.4	63
Wildlife in stream	39.7	22.0	39.7	0
Straight pipes	1.8	1.0	0.0	100
Total	**180.3**	**100.0**	**90.1**	**50**

[a] Only impaired subwatersheds (2507 and 2308) and unimpaired subwatersheds (2502 and 2503) upstream of impaired subwatersheds

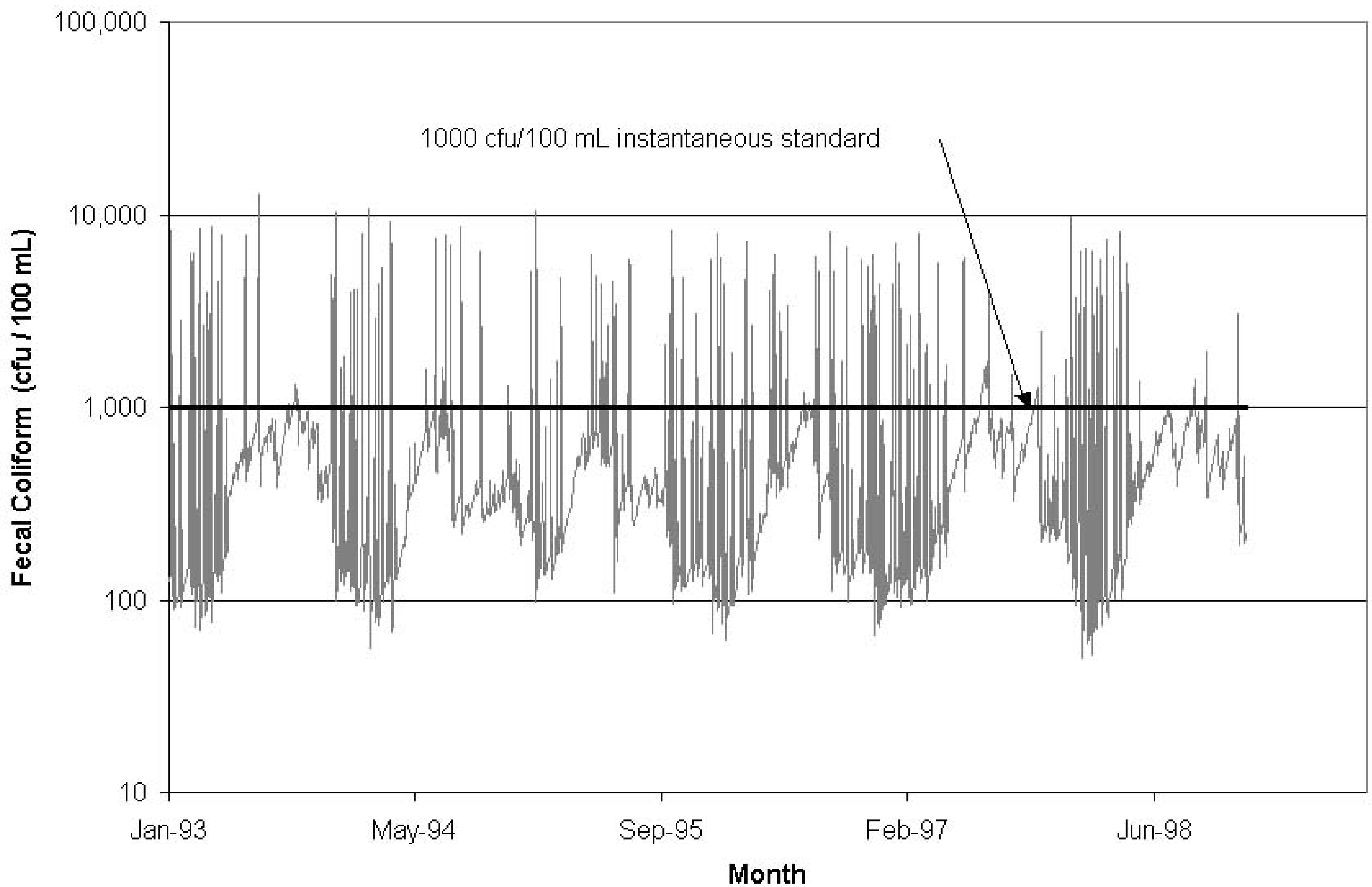

Figure 9.2. Phase 1 TMDL implementation scenario for Elk Creek

9.3.3 Machine Creek Watershed

Several loadings reduction scenarios from Machine Creek were considered. As shown in Table 9.7, Scenario 5 meets the Phase 1 implementation goal of 10% or less violation of the 1,000 cfu/100 mL instantaneous standard. The scenario selected for Phase 1 implementation requires an 80% reduction in direct deposit of manure to stream by cattle. There are no direct pipes in the watershed. Fecal coliform concentrations resulting from Scenario 5 implementation are presented graphically in Figure 9.3. Loadings for the existing allocation and Phase 1 allocation scenario for nonpoint and direct nonpoint sources are presented in Tables 9.8 and 9.9, respectively. The loadings in Tables 9.8 and 9.9 include contributions from all subwatersheds.

Table 9.7. Phase 1 implementation scenarios for Machine Creek watershed (L26a)

Scenario	Percent Reduction in Direct Deposit from Cattle	Percent Reduction in Direct Deposit from Wildlife	Percent Reduction in Straight Pipes	Loads from Pervious Land Surfaces	Percent Exceedances of 1000 cfu/100 mL Standard
1	0	0	0	0	43.6
2	90	0	0	0	9.2
3	85	0	0	0	9.3
4	75	0	0	0	10.4
5*	**80**	**0**	**0**	**0**	**10.0**

[a] Recommended Implementation scenario

Table 9.8. Annual nonpoint source fecal coliform loading reductions for Phase 1 TMDL implementation of Scenario 5 in the Machine Creek watershed (L26a)

Land use Category	Existing Conditions		Implementation Scenario	
	Existing load ($x\ 10^{12}$ cfu)	Percent of total load to stream from nonpoint sources	TMDL nonpoint source allocation load ($x\ 10^{12}$ cfu)	Percent reduction from existing load
Commercial/Industrial	<0.01	< 0.1	<0.01	0
Cropland	0.13	< 0.1	0.13	0
Forest	1.49	0.2	1.49	0
High Density Residential	0.01	< 0.1	0.01	0
Pasture	996.32	99.5	996.32	0
Rural Residential	3.30	0.3	3.30	0
Total	**1,001.24**	**100.0**	**1,001.24**	**0**

Table 9.9. Annual direct nonpoint source fecal coliform loading reductions for Phase 1 TMDL implementation of Scenario 4 in the Machine Creek watershed (L26a)

	Existing Conditions		Implementation Scenario	
Source	Fecal coliform loading ($\times 10^{12}$ cfu/year)	Percent of total loading	Nonpoint source ($\times 10^{12}$ cfu/year)	Percent reduction from existing loads
Cattle in stream	126.6	79.86	25.3	80
Wildlife in stream	31.9	20.14	31.9	0
Straight pipes	0.0	0.0	0.0	0
Total	**158.5**	**100**	**57.2**	**64**

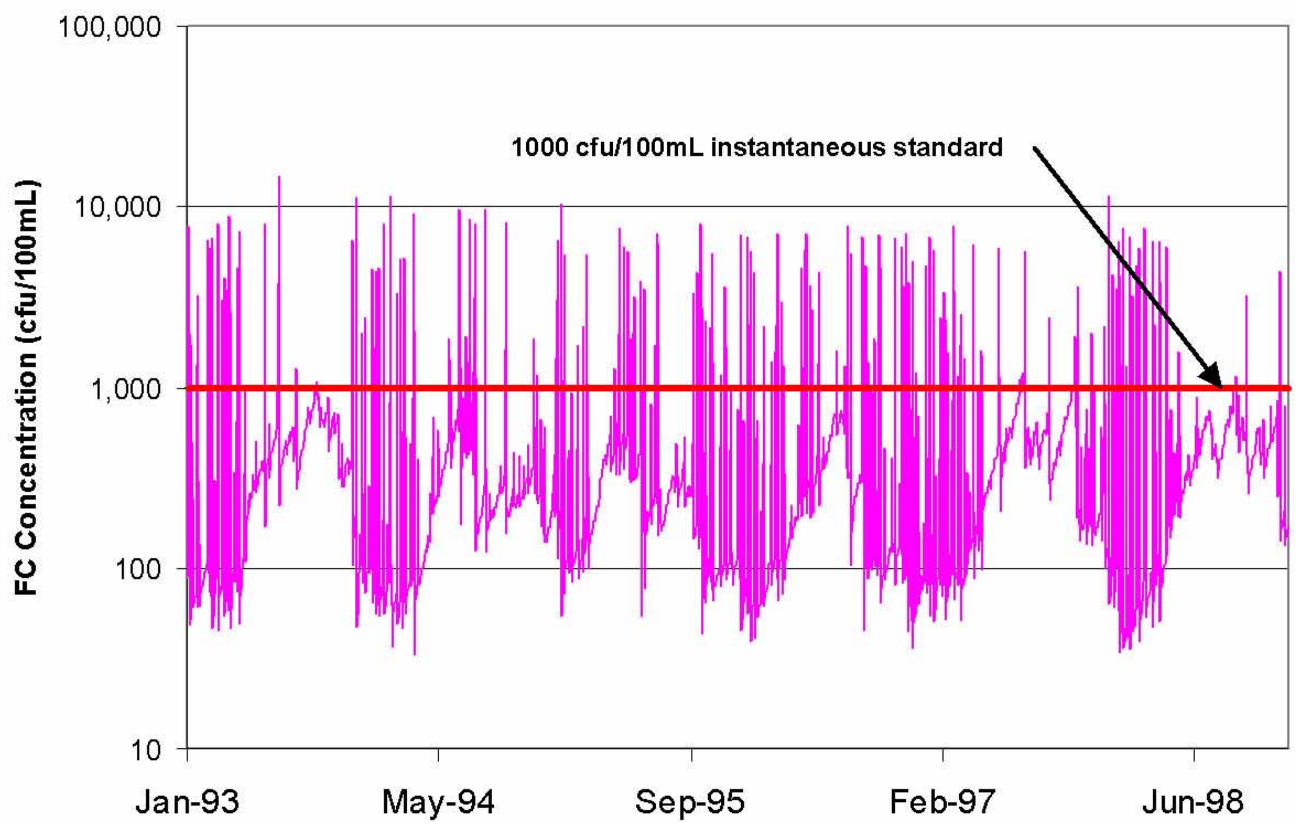

Figure 9.3. Phase 1 TMDL implementation scenario for Machine Creek

9.3.4 Little Otter River Watershed

Ten loadings implementation reduction scenarios from the Little Otter River were considered. As shown in Table 9.10, Scenarios 9 and 10 meet the Phase 1 implementation goal of 10% or less violation of the 1,000 cfu/100 mL instantaneous standard. The final scenario selected for Phase 1 implementation, Scenario 10, allows for limited access to the stream by cattle. Furthermore, the Phase I implementation requires no reduction in wildlife contributions; a 30% reduction from pervious agricultural land surfaces (pasture and cropland) and elimination of straight pipes. No reductions in CSO from the Bedford STP are needed to meet the Phase 1 implementation goal. Fecal coliform concentrations resulting from Scenario 10 implementation are presented graphically in Figure 9.4. Loadings for the existing allocation and Phase 1 allocation scenario for nonpoint and direct nonpoint sources are presented in Tables 9.11 and 9.12.

Table 9.10. Phase 1 implementation scenarios for Little Otter River watershed (L26b)

Scenario	Percent Reduction in Direct Deposit from Cattle	Percent Reduction in Direct Deposit from Wildlife	Percent Reduction in Straight Pipes	Loads from Pervious Agricultural Land Surfaces	Bedford CSO	Percent Exceedances of 1000 cfu/100 mL Standard
1	0	0	0	0	0	44.7
2	0	0	100	0	0	12.3
3	50	0	100	0	0	12.2
4	75	0	100	0	0	11.7
5	90	0	100	0	0	11.6
6	90	0	100	25	0	10.3
7	95	0	100	25	0	10.3
8	90	0	100	35	0	10.3
9	85	0	100	35	0	9.6
10[a]	**85**	**0**	**100**	**30**	**0**	**9.9**

[a] Recommended implementation scenario.

Table 9.11. Annual nonpoint source fecal coliform loading reductions for Phase 1 TMDL implementation of Scenario 10 in the Little Otter River watershed (L26b)

Land use Category	Existing Conditions		Implementation Scenario	
	Existing load (x 10^{12} cfu)	Percent of total load to stream from nonpoint sources	TMDL nonpoint source allocation load (x 10^{12} cfu)	Percent reduction from existing load
Commercial/Industrial	0.01	< 0.1	0.01	0
Cropland	0.11	< 0.1	0.08	30
Forest	8.14	0.2	8.14	0
High Density Residential	78.11	2.4	78.11	0
Pasture	3,136.00	96.6	2,195.20	30
Rural Residential	24.87	0.8	24.87	0
Total	**3,247.24**	**100.0**	**2,306.41**	**29.0**

Table 9.12. Annual direct nonpoint source fecal coliform loading reductions for Phase 1 TMDL implementation of Scenario 10 in the Little Otter River watershed (L26b)

Source	Existing Conditions		Implementation Scenario	
	Fecal coliform loading ($\times$ 10^{12} cfu/year)	Percent of total loading	Nonpoint source ($\times$ 10^{12} cfu/year)	Percent reduction from existing loads
Cattle in stream	130.4	75.29	19.6	85
Wildlife in stream	41.0	23.68	41.0	0
Straight pipes	1.8	1.03	0.0	100
Total	**173.2**	**100.0**	**60.6**	**65.0**

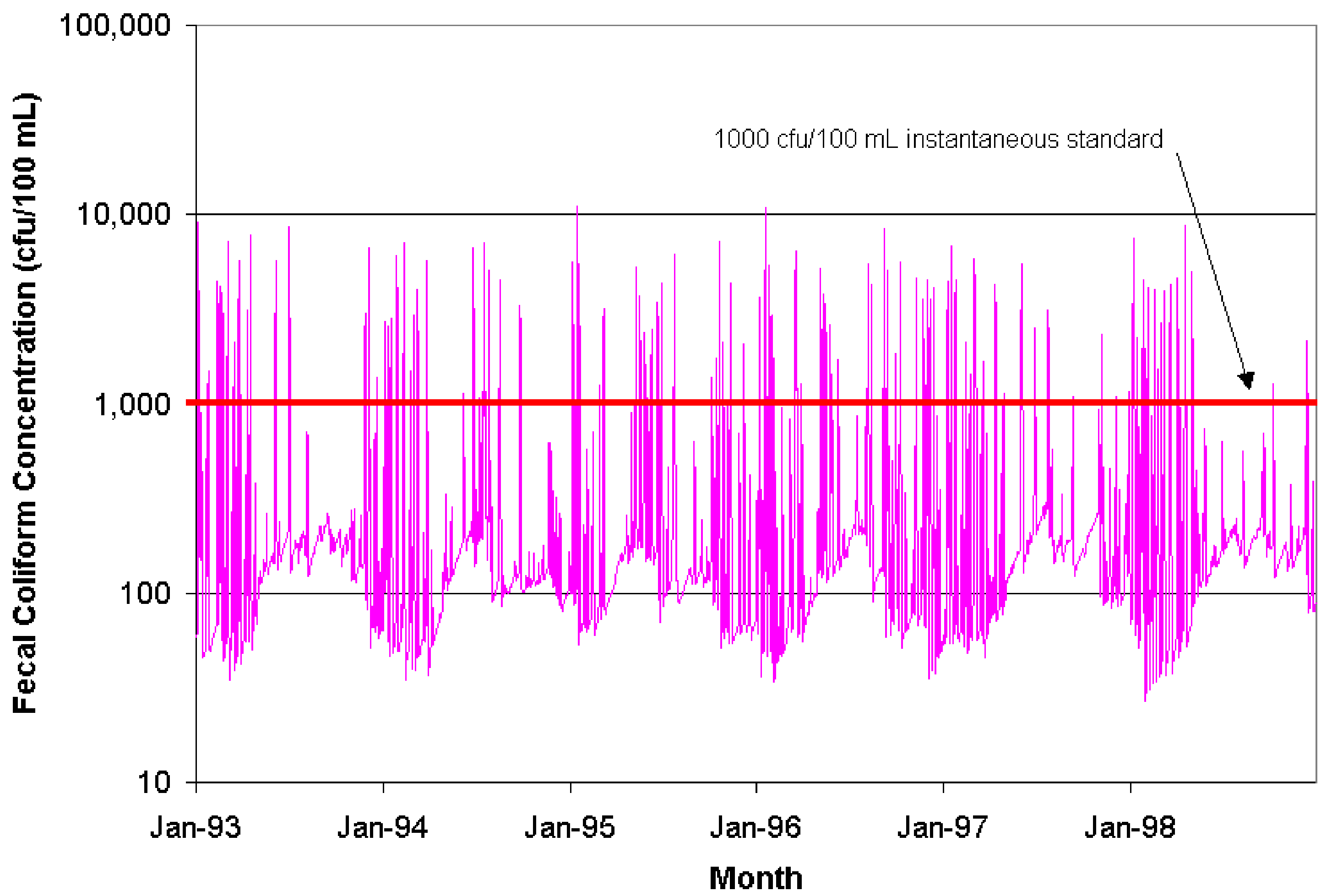

Figure 9.4. Phase 1 TMDL implementation scenario for Little Otter River

9.3.5 Phase I Lower Big Otter River Watershed

Six loadings reduction scenarios from the Lower Big Otter River were considered. As shown in Table 9.13, Scenario 3 meets the Phase 1 implementation goal 10% or less violation of the 1,000 cfu/100 mL instantaneous standard. The phase 1 implementation assumes full implementation of the phase 1 TMDL in Machine Creek, Little Otter River, Elk Creek and Sheep Creek. Except for elimination of the straight pipes, no other reductions in loads from other sources within the Lower Big Otter River watershed are needed to meet the phase 1 implementation goal. Fecal coliform concentrations resulting from Scenario 3 implementation are presented graphically in Figure 9.5. Loadings for the existing allocation and Phase 1 allocation scenario for nonpoint and direct nonpoint sources are presented in Tables 9.14 and 9.15.

Table 9.13. Phase 1 implementation scenarios for the Lower Big Otter River watershed (L28)

Scenario	Percent Reduction in Direct Deposit from Cattle	Percent Reduction in Direct Deposit from Wildlife	Percent Reduction in Straight Pipes	Loads from Pervious Land Surfaces	Percent Exceedances of 1000 cfu/100 mL Standard
1[a]	0	0	100	0	27.1%
2[a]	100	0	100	0	25.5%
3[b,c]	**0**	**0**	**100**	**0**	**9.9%**
4[d]	0	0	100	0	10.3%
5[d]	100	0	100	0	10.3%

[a] Existing Conditions in Upstream watersheds

[b] Recommended implementation scenario

[c] Phase I plans implemented in Machine Creek, Little Otter River, Elk Creek, and Sheep Creek

[d] Phase I plans implemented in Machine Creek and Little Otter River

Table 9.14. Annual nonpoint source fecal coliform loading reductions for Phase 1 TMDL implementation of Scenario 3 in the Lower Big Otter River watershed (L28)

Land use Category	Existing Conditions		Implementation Scenario	
	Existing load (x 10^{12} cfu)	Percent of total load to stream from nonpoint sources	TMDL nonpoint source allocation load (x 10^{12} cfu)	Percent reduction from existing load
Commercial/Industrial	0.01	< 0.1	0.01	0
Cropland	0.17	< 0.1	0.17	0
Forest	86.26	4.1	86.26	0
High Density Residential	0.55	< 0.1	0.55	0
Rural Residential	1,998.26	94.4	1,998.26	0
Pasture	31.54	1.5	31.54	0
Total	**2,116.78**	**100.0**	**2,116.78**	**0**

Table 9.15. Annual direct nonpoint source fecal coliform loading reductions for Phase 1 TMDL implementation of Scenario 3 in the Lower Big Otter River watershed (L28)

Source	Existing Conditions		Implementation Scenario	
	Fecal coliform loading ($\times 10^{12}$ cfu/year)	Percent of total loading	Nonpoint source ($\times 10^{12}$ cfu/year)	Percent reduction from existing loads
Cattle in stream	96.1	69.2	96.1	0
Wildlife in stream	40.9	29.5	40.9	0
Straight pipes	1.8	1.3	0.0	100
Total	**138.8**	**100.0**	**137.0**	**1.3%**

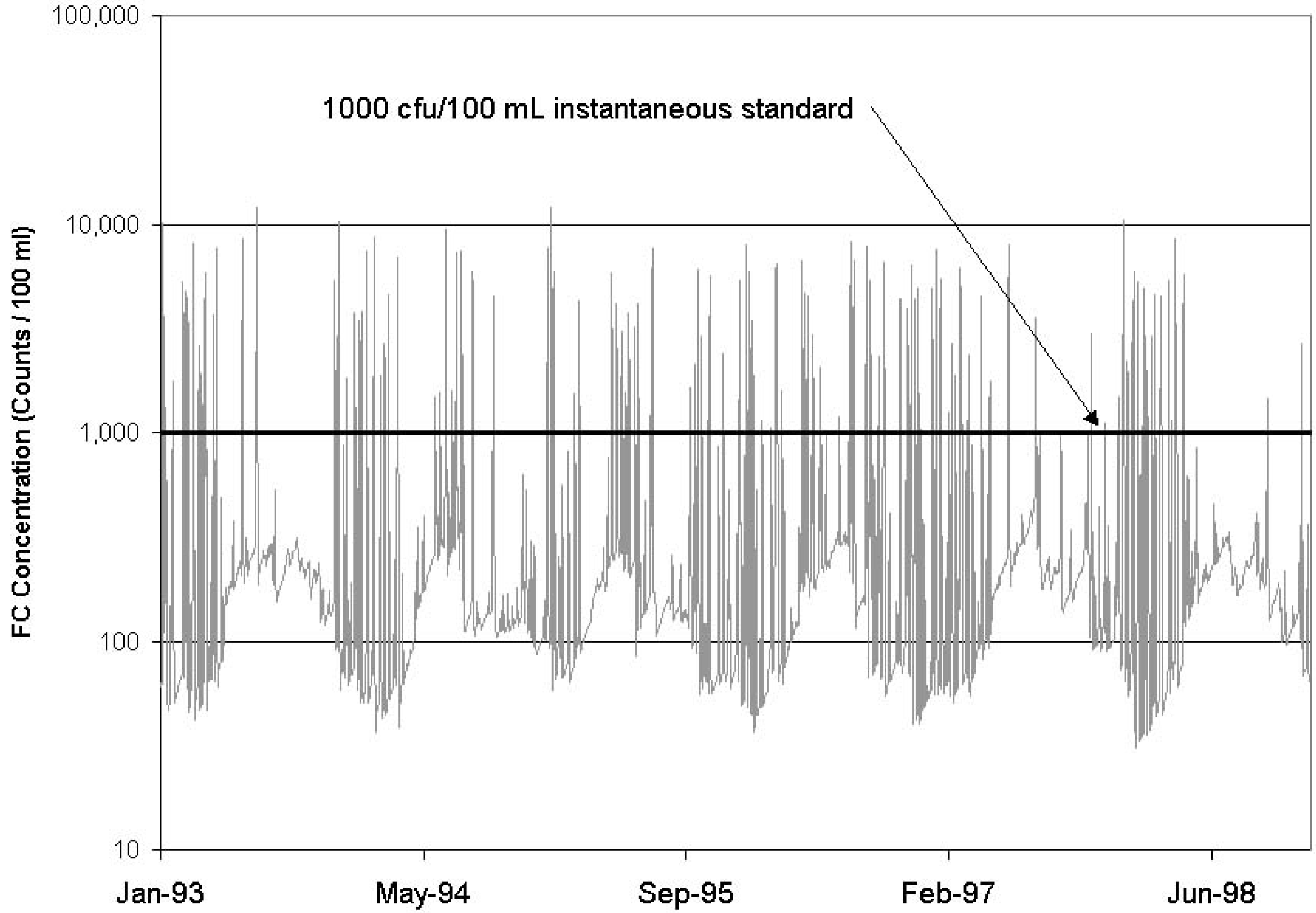

Figure 9.5. Phase 1 TMDL implementation scenario for the Lower Big Otter River

9.4 Wildlife and Water Quality Standards

9.4.1 Wildlife Contributions

The DEQ and DCR have developed fecal coliform TMDLs for a number of impaired waters in the State. In some of the streams, fecal coliform bacteria counts contributed by wildlife result in standards violations, particularly during base flow conditions. Wildlife densities obtained from the Department of Game and Inland Fisheries and analysis or “typing” of the fecal coliform bacteria show that the high densities of muskrat, beaver, and waterfowl are responsible for the elevated fecal bacteria counts in these streams.

9.4.2 Designated Use

All waters in the Commonwealth have been designated as "primary contact" for the swimming use regardless of size, depth, location, water quality or actual use. The fecal coliform bacteria standard is described in 9 VAC 25-260-170. This standard is to be met during all stream flow levels and was established to protect bathers from ingestion of potentially harmful bacteria. However, many headwater streams are small and shallow during base flow conditions when surface runoff has minimal influence on stream flow. Even in pools, these shallow streams do not allow full body immersion during periods of base flow. In larger streams, lack of public access often precludes the swimming use.

Base flow conditions of a stream occur at a higher frequency than flow conditions influenced by precipitation runoff events. As a result, the vast majority of the water quality sampling in the watershed used to determine the impairment occurred during base flow conditions. Therefore, a critical period for modeling to insure the attainment of water quality standards is during base flow conditions with little or no storm runoff.

In the TMDL public participation process, the residents in these watersheds often report that " people do not swim in this stream.” It is obvious that many streams within the state are not used for recreational purposes. In many cases, insufficient depth of the streams along with other physical factors and lack of public accessibility do not provide suitable conditions for swimming or primary contact recreation.

9.4.3 TMDL Allocations

The wildlife contributions of fecal bacteria from muskrats, beavers, and waterfowl are at their highest counts during base flow conditions when there is little or no pollutant wash-off from the adjacent land areas. Therefore base flow events represent the critical condition because the allocations needed to attain water quality standards during these flow regimes insure that standards were met in all other flow ranges.

For many of these streams, even the removal of all of the sources of fecal coliform (other than wildlife) does not allow the stream to attain standards during these critical conditions (or low flows). TMDL allocation reductions of this magnitude are not realistic and do not meet EPA's guidance for reasonable assurance. Based on the water quality modeling, many of these streams will not be able to attain standards without some reduction in wildlife. Virginia and EPA are not proposing the elimination of wildlife to allow for the attainment of water quality standards. This is obviously an impractical action. Clearly, the reduction of wildlife or changing a natural background condition is not the intended goal of a TMDL or any other federal and state water quality management programs.

9.4.4 Options for Resolution of Wildlife Problem

To address the wildlife problem, EPA and Virginia have developed a TMDL strategy that will provide the reasonable assurance necessary under EPA guidance. The first step in this strategy is to develop a phased approach for the attainment of water quality standards in the TMDL. The first phase is to select an interim reduction goal. This goal is to be selected by the stakeholders in the watershed and Virginia for EPA's approval. In the interim goal or target, the pollutant reductions contained in the allocation would be made only on controllable sources identified in the TMDL, setting aside any reduction of wildlife. During the first phase, all reductions from controllable sources called for in the TMDL allocation would be reduced to their appropriate levels. The first phase would be a labor-intensive process that could occur on an incremental basis. While the first phase is underway, Virginia would be working concurrently on the second phase to address the wildlife issue.

Following completion of the first phase reductions, the DEQ would re-assess the streams to determine if water quality standards had been attained. This effort will also determine if the modeling assumptions and approaches are correct. If it were found that water quality standards are not met, the second phase allocations would be initiated at a level necessary to meet existing standards. In some cases, the effort may never have to go to the second phase.

The second phase of the TMDL will result in the attainment of water quality standards. This phase involves a number of components outlined below:
EPA has recommended that all States adopt an *E. coli* or enterococci standard for fresh water and enterococci criteria for marine waters by 2003. EPA is pursuing the States' adoption of these standards because there is a stronger correlation between the concentration of these organisms (*E. coli* and enterococci) and the incidence of gastrointestinal illness than with fecal coliform. *E-coli* and enterococci are both bacteriological organisms that can be found in the intestinal tract of warm-blooded animals. Like fecal coliform bacteria, these organisms indicate the presence of fecal contamination. The adoption of the *E. coli* and enterococci standard is scheduled for 2002 in Virginia.

Recognizing that all waters in the Commonwealth are not used extensively for swimming, VA is currently looking at re-designation of the swimming use based on actual swimming frequency and risk assessment. The new designation of the swimming use could contain the following 4 levels:
Designated bathing beach (currently all waters protected to this level),
Moderate swimming,
Low swimming, and
Infrequent swimming.

Each of the four swimming use levels would have protection criterion based on risk analysis. The current high levels of protection would continue to be applied to waters in which people are more likely to engage in an activity that results in the ingestion of water. The primary contact recreational uses recommended above are from EPA's Ambient Water Quality Criteria for Bacteria, 1986.

The re-designation of the current swimming use will require the completion of a use attainability analysis. A Use Attainability Analysis (UAA), is a structured scientific assessment of the factors affecting the attainment of the use which may include physical, chemical, biological, and economic factors as described in the Federal Regulations. The stakeholders in the watershed, Virginia, and EPA will have an opportunity to comment on these special studies.

Most states apply their water quality standards only to flows above a statistical low flow frequency that is defined as a 7-day average occurring once every 10 years (7Q10). However Virginia's fecal coliform bacteria standard is applied to all flows. Some head water streams have very minimal flow during periods of low precipitation or droughts. During such low flow events, the counts of fecal coliform bacteria deposited directly into the stream are concentrated because the small flow is unable to dilute the deposition of wastes. In order to attain standards during low flow conditions, it is necessary to reduce the amount of waste deposited directly to the stream. Sources of these wastes include cattle in-stream, wildlife in-stream, septic systems, and wastes conveyed directly to the stream from milking parlors. By applying the standard only to flows greater than 7Q10, the TMDL would not need to insure the attainment of standards during extreme drought flow conditions when stream flow falls below 7Q10.

Another option that EPA allows for the states is to adopt site specific criteria based on natural background levels of fecal coliforms. The State must demonstrate that the source of fecal contamination is natural and uncontrollable by effluent limitations and BMPs.

9.5 Public Participation

The first public meeting was public noticed on 28 February 2000 in the Virginia Register., The Peaks of Otter Soil and Water Conservation District (SWCD) posted the notice in local agricultural supply stores and the USDA/FSA Service Center. This meeting was held in Bedford, VA on 16 March 2000 to discuss the development of the TMDL. Copies of the presentation materials and diagrams outlining the development of the TMDL were available for public distribution at the meeting. Approximately 46 people attended the meeting. The public comment period ended on 28 March 2000.

A survey of approximately 600 farm operators in the watershed was used to assess agricultural practices. The survey was a joint effort between Virginia Tech and the Peaks of Otter SWCD. The survey cover letter announced the series of three public meetings, the purpose of the meetings, and information on meeting time and location. Included with the survey was an announcement for a producer's meeting to be held on 25 April 2000. Ninety-two surveys were completed and returned and 21 stakeholders attended the producer's meeting.

The second public meeting was public noticed on 8 May 2000 in the Virginia Register. The notice was printed in the Lynchburg News & Advance on 14 May 2000. In addition, a letter of notification was sent to each stakeholder on the SWCD mailing list. This meeting was held in Bedford, VA on 23 May 2000 to discuss the hydrologic calibration and input data for the TMDL. Copies of the presentation materials and a fact sheet were distributed at the meeting. Approximately 38 people attended the meeting. The public comment period ended on 5 June 2000.

The third public meeting was public noticed on 17 July 2000 in the Virginia Register. This meeting was held in Bedford, VA on 2 August 2000 to discuss the draft TMDL. Copies of the draft TMDL were distributed at the meeting. Approximately 40 people attended the meeting. The public comment period ended on 14 August 2000. There were no written comments submitted by the general public.

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11 GLOSSARY

Allocation

That portion of a receiving water's loading capacity that is attributed to one of its existing or future pollution sources (nonpoint or point) or to natural background sources.

Allocation Scenario

A proposed series of point and nonpoint source allocations (loadings from different sources), which are being considered to meet a water quality planning goal.

Background levels

Levels representing the chemical, physical, and biological conditions that would result from natural geomorphological processes such as weathering and dissolution.

BASINS (Better Assessment Science Integrating Point and Nonpoint Sources)

A computer-run tool that contains an assessment and planning component that allows users to organize and display geographic information for selected watersheds. It also contains a modeling component to examine impacts of pollutant loadings from point and nonpoint sources and to characterize the overall condition of specific watersheds.

Best Management Practices (BMP)

Methods, measures, or practices that are determined to be reasonable and cost-effective means for a land owner to meet certain, generally nonpoint source, pollution control needs. BMPs include structural and nonstructural controls and operation and maintenance procedures.

Calibration

The process of adjusting model parameters within physically defensible ranges until the resulting predictions give a best possible good fit to observed data.

Die-off (of fecal coliform)

Reduction in the fecal coliform population due to predation by other bacteria as well as by adverse environmental conditions (e.g., UV radiation, pH).

Direct nonpoint sources

Sources of pollution that are defined statutorily (by law) as nonpoint sources that are represented in the model as point source loadings due to limitations of the model. Examples include: direct deposits of fecal material to streams from livestock and wildlife.

E-911 digital data

Emergency response database prepared by the county that contains graphical data on road centerlines and buildings. The database contains approximate outlines of buildings, including dwellings and poultry houses.

Failing septic system

Septic systems in which drain fields have failed such that effluent (wastewater) that is supposed to percolate into the soil, now rises to the surface and ponds on the surface where it can flow over the soil surface to streams or contribute pollutants to the surface where they can be lost during storm runoff events.

Fecal coliform

A type of bacteria found in the feces of various warm-blooded animals that is used as indicator of the possible presence of pathogenic (disease causing) organisms.

Geometric mean

The geometric mean is simply the nth root of the product of n values. Using the geometric mean, lessens the significance of a few extreme values (extremely high or low values). In practical terms, this means that if you have just a few bad samples, their weight is lessened.

Mathematically the geometric mean, $\overline{x}_g$, is expressed as:

$$\overline{x}_g = \sqrt[n]{x_1 \times x_2 \times \ldots \times x_n}$$

where n is the number of samples, and x_i is the value of sample i.

HSPF (Hydrological Simulation Program-Fortran)

A computer-based model that calculates runoff, sediment yield, and fate and transport of various pollutants to the stream. The model was developed under the direction of the U.S. Environmental Protection Agency (EPA).

Hydrology

The study of the distribution, properties, and effects of water on the earth’s surface, in the soil and underlying rocks, and in the atmosphere.

Instantaneous criterion

The instantaneous criterion or instantaneous water quality standard is the value of the water quality standard that should not be exceeded at any time. For example, the Virginia instantaneous water quality standard for fecal coliform is 1,000 cfu/100 mL. If this value is exceeded at any time, the water body is in violation of the state water quality standard.

Load allocation (LA)

The portion of a receiving water's loading capacity that is attributed either to one of its existing or future nonpoint sources of pollution or to natural background.

Margin of Safety (MOS)

A required component of the TMDL that accounts for the uncertainty about the relationship between the pollutant loads and the quality of the receiving waterbody. The MOS is normally incorporated into the conservative assumptions used to develop TMDLs (generally within the calculations or models). The MOS may also be assigned explicitly, as was done in this study, to ensure that the water quality standard is not violated.

Model

Mathematical representation of hydrologic and water quality processes. Effects of Land use, slope, soil characteristics, and management practices are included.

Nonpoint source

Pollution that is not released through pipes but rather originates from multiple sources over a relatively large area. Nonpoint sources can be divided into source activities related to either land or water use including failing septic tanks, improper animal-keeping practices, forest practices, and urban and rural runoff.

Pathogen

Disease-causing agent, especially microorganisms such as bacteria, protozoa, and viruses.

Point source

Pollutant loads discharged at a specific location from pipes, outfalls, and conveyance channels from either municipal wastewater treatment plants or industrial waste treatment facilities. Point sources can also include pollutant loads contributed by tributaries to the main receiving water stream or river.

Pollution

Generally, the presence of matter or energy whose nature, location, or quantity produces undesired environmental effects. Under the Clean Water Act for example, the term is defined as the man-made or man-induced alteration of the physical, biological, chemical, and radiological integrity of water.

Reach

Segment of a stream or river.

Runoff

That part of rainfall or snowmelt that runs off the land into streams or other surface water. It can carry pollutants from the air and land into receiving waters.

Septic system

An on-site system designed to treat and dispose of domestic sewage. A typical septic system consists of a tank that receives liquid and solid wastes from a residence or business and a drainfield or subsurface absorption system consisting of a series of tile or percolation lines for disposal of the liquid effluent. Solids (sludge) that remain after decomposition by bacteria in the tank must be pumped out periodically.

Simulation

The use of mathematical models to approximate the observed behavior of a natural water system in response to a specific known set of input and forcing conditions. Models that have been validated, or verified, are then used to predict the response of a natural water system to changes in the input or forcing conditions.

Straight pipe

Delivers wastewater directly from a building, e.g., house, milking parlor, to a stream, pond, lake, or river.

Total Maximum Daily Load (TMDL)

The sum of the individual wasteload allocations (WLA's) for point sources, load allocations (LA's) for nonpoint sources and natural background, plus a margin of safety (MOS). TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measures that relate to a state's water quality standard.

Urban Runoff

Surface runoff originating from an urban drainage area including streets, parking lots, and rooftops.

Validation (of a model)

Process of determining how well the mathematical model's computer representation describes the actual behavior of the physical process under investigation.

Wasteload allocation (WLA)

The portion of a receiving water's loading capacity that is allocated to one of its existing or future point sources of pollution. WLAs constitute a type of water quality-based effluent limitation.

Water quality standard

Law or regulation that consists of the beneficial designated use or uses of a water body, the numeric and narrative water quality criteria that are necessary to protect the use or uses of that particular water body, and an anti-degradation statement.

Watershed

A drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.

APPENDIX A

Sample Calculation: Distribution of Dairy Cattle

(Sheep Creek watershed (L23), subwatershed 2302 during January)

Sample Calculation: Distribution of Dairy Cattle

(Sheep Creek watershed (L23), subwatershed 2302 during January)

(Note: Due to rounding, the numbers may not add up.)

Breakdown of the dairy herd as presented in Table 4.6 is 34.7% milk cows, 6.7% dry cows, and 58.6% heifers.

Dairy cattle population	=	314.0		
Milk cow population	=	314.0 * (34.7%)	=	109.0
Dry cow population	=	314.0 * (6.7%)	=	21.0
Heifer population	=	314.0 * (58.6%)	=	184.0

During January, milk cows are confined 60.0% of the time (Table 2.8). Dry cows and heifers are not confined.

Milk cows in confinement	=	109.0 * (60%)	=	65.4

When not confined, milk cows are on the pasture or in the stream. Dry cows and heifers are assumed to spend all their time on the pasture and in the stream.

Milk cows on pasture and in the stream	=	(109.0 – 65.4)	=	43.6
Dry cows on pasture and in the stream			=	21.0
Heifers on pasture and in the stream			=	184.0

Seventy nine percent of the pasture acreage has stream access (Table 4.7). Hence dairy cattle with stream access are calculated as:

Milk cows on pastures with stream access	=	43.6*(79%)	=	34.4
Dry cows on pastures with stream access	=	21.0*(79%)	=	16.6
Heifers on pastures with stream access	=	184*(79%)	=	145.4

Dairy cattle in and around the stream are calculated using the numbers in Step 4 and the number of hours cattle spend in the stream in January (Table 2.8) as:

Milk cows in and around streams	=	34.4*(0.5/24)	=	0.7
Dry cows in and around streams	=	16.6*(0.5/24)	=	0.4
Heifers in and around streams	=	145.4*(0.5/24)	=	3.0

Number of cattle defecating in the stream is calculated by multiplying the number of cattle in and around the stream by 30% (Section 4.2).

Milk cows defecating in streams	=	0.7*(30%)	=	0.2
Dry cows defecating in streams	=	0.4*(30%)	=	0.1
Heifers defecating in streams	=	3.0*(30%)	=	0.9

After calculating the number of cattle defecating in the stream, the number of cattle defecating on the pasture is calculated by subtracting the number of cattle defecating in the stream (Step 6) from number of cattle in pasture and stream (Step 3).

Milk cows defecating on pasture	=	(43.6 – 0.2)	=	43.4
Dry cows defecating on pasture	=	(21.0 – 0.1)	=	20.9
Heifers defecating on pasture	=	(184.0 – 0.9)	=	183.1

APPENDIX B

Weather Data Preparation

Weather Data Preparation

Summary

A weather data file for providing the weather data inputs into the HSPF Model was created for the period January 1980 through September 1999 using the WDMUtil. Raw data required for creating the weather data file included hourly precipitation (in.), maximum, minimum, and dew point daily temperatures (°F), average daily wind speed (mi./h), total daily solar radiation (langleys), and percent sun. The primary data source was the National Climatic Data Center's (NCDC) Cooperative Weather Station at Lynchburg Regional Airport, Campbell Co., Virginia; data from Altavista NCDC station were also used. Daily solar radiation data was generated using CLIGEN[1]. The raw data required varying amounts of preprocessing prior to input into WDMUtil or within WDMUtil to obtain the following hourly values: precipitation (PREC), air temperature (ATEM), dew point temperature (DEWP), solar radiation (SOLR), wind speed (WIND), potential evapotranspiration (PEVT), potential evaporation (EVAP), and cloud cover (CLOU).

Raw data collection and processing

Weather data in the variable length format were obtained from the NCDC's weather stations in Lynchburg Regional Airport, VA (Lat./Long. 37.3N/79.2W, elevation 940 ft), and Altavista, VA (Lat./Long.37.1N/79.3'W, elevation 510 ft). While deciding on the period of record for the weather WDM file, availability of flow and water quality data was considered in addition to the availability and quality of weather data. Hence, the weather WDM file was prepared for the January 1980 through September 1999 period. Only precipitation data were obtained for Altavista weather station since most of the other weather parameters were not measured at Altavista station. In the following pages, the procedures used to process the raw data to obtain finished data required for preparing the WDM file are described.

Hourly precipitation

Hourly precipitation (PREC) data were requested from the NCDC for Lynchburg Regional Airport and Altavista for the period 1980 through 1999 in variable length format. The file obtained from NCDC was saved as a text file and then renamed as an NCD file before it could be read by WDMUtil.

The PREC record for the January 1980 through September 1999 period (7213 days) did not include any missing hourly precipitation data for Lynchburg Regional Airport. However, for Altavista, there was a total of 7541 (4.35% of total record of 173,112 hours) missing hourly precipitation data and 2749 (1.59% of total record of 173,112 hours) hours of missing record. The *missing record* represents certain number of consecutive missing data of hourly precipitation while the total depth of rainfall during these hours is given at the end of the missing period. On the other hand, *missing values* are those for which the hourly precipitation value as well as the total depth of precipitation during the missing period are missing. These two different types of missing hourly precipitation data were filled differently.

The following options were used to fill in the missing hourly data.

a. For the *missing record* in the hourly precipitation at Altavista, the total depth of rainfall during the *missing record* period was disaggregated into hourly values based on the hourly precipitation distribution observed at Lynchburg Regional Airport.

b. For the *missing values* in the hourly precipitation at Altavista, the daily precipitation from the same station (Altavista) was disaggregated into hourly values based on the hourly precipitation distribution observed at Lynchburg Regional Airport.

Temperature

Separate daily maximum temperature (TMAX) and daily minimum temperature (TMIN) files in variable length format were obtained from NCDC for Lynchburg Regional Airport. There were no missing maximum and minimum temperature data for the entire period (January 1980 to September 1999). The files were saved as NCD files. Daily average dewpoint temperature (DPTP) data were missing for the years 1980 through 1983 at Lynchburg Regional Airport station; those years of data were filled with DPTP data from the consecutive four years (1984 through 1987). The DISAGGREGATE function in WDMUtil was used to calculate hourly air temperature (ATEM) for the modeling period from TMAX and TMIN. Similarly, the DISAGGREGATE function was used to calculate hourly dew point temperature (DEWP) from DPTP.

Average daily wind speed

Average daily wind speed (DWND) data was obtained for NCDC's station at Lynchburg Regional Airport. The DWND data that were missing for the years 1980 through 1983 and were replaced with DWND for the years 1984 through 1987. The variable length format file received from NCDC gave average daily wind speed in TL (tenths of mi./h). Since the file also contained the units of TK (tenths of knot/h), the file required modification to express the units only in TL. However, it was observed that WDMUtil read the file as mi./h and not as tenths of mi./h. Hence, the file read as mi./h was saved as a text file in WDMUtil. The text file was opened in EXCEL. The values were converted to mi./d and the date field was modified to have four-digit years (mm/dd/yyyy); WDMUtil cannot read a date field with a two-digit year. The resulting file was saved as an ASCII flat file. A flat file cannot be created from the NCD file and considerable preprocessing is required if the WDMUtil is not used. The flat file was read back into WDMUtil to obtain DWND in mi/d. The DISAGGREGATE function in WDMUtil was used to obtain hourly wind speed (WIND) in mi/h.

Total daily solar radiation (DSOL)

Solar radiation data is neither collected at Lynchburg Regional Airport, nor at Altavista. Therefore, synthetic DSOL was generated for Buchanan, VA (Lat./ Long. 37.1N/82.1W, elevation 1600 ft) using CLIGEN in the WEPP input format. The resulting file was processed in EXCEL to obtain a text file with one column of days and another column of total daily solar radiation (ly) and with a date field with four-digit years. The modified DSOL text file was successfully read into WDMUtil. The DISAGGREGATE function in WDMUtil was used to obtain hourly solar radiation (SOLR).

Percent sun (PSUN)

Daily Cloud Cover (DCLO) was measure at Lynchburg Regional Airport, however, DCLO data were missing for the period of August/1996 through September/1999. This missing data were replaced by the preceding period of August/1992 through September/1995. The DCLO data are used by WDMUtil to compute daily solar radiation (DSOL). The DSOL data are disaggregated in WDMUtil to produce hourly solar radiation data (SOLR).

Input data and processing in WDMUtil required for HSPF input parameters

The input data and WDMUtil processing required for calculating hourly weather data required for use in HSPF are discussed above. Other parameters such as hourly Penman pan (potential) evaporation (EVAP) and hourly potential evapotranspiration (PEVT) require more than one type of input data. Table B.2 summarizes all the parameters that are required in modeling in HSPF as well as the inputs and methods required for calculating the parameters.

Table B.2. Weather parameters and processing in WDMUtil required for HSPF modeling

Input parameters	WDMUtil functions	HSPF parameter
PREC	No further processing required	PREC
TMAX and TMIN	DISAGGREGATE	ATEM
DPTP	DISAGGREGATE	DEWP
DSOL	DISAGGREGATE	SOLR
DWND	COMPUTE	WIND
TMAX and TMIN DEVT	COMPUTE DISAGGREGATE	DEVT (Hamon)[a] PEVT
TMAX, TMIN, DPTP, DWND, DSOL DEVP	COMPUTE DISAGGREGATE[b]	DEVP (Penman)[a] EVAP
DCLO DSOL	COMPUTE DISAGGREGATE[c]	DSOL SOLR

[a] Parameters not required by HSPF
[b] DISAGGREGATE function for DEVT used
[c] DISAGGREGATE function for DWND used

[1]CLIGEN – Climatic Generator, a program used to generate weather parameters using historic data

APPENDIX C

Die-off of Fecal Coliform During Storage

Die-off of Fecal Coliform During Storage

The following procedure was used to calculate amount of fecal coliform produced in confinement in dairy manure applied to cropland and pasture. All calculations were performed on spreadsheet for each subwatershed with dairy operations in a watershed.

1. It was determined from the producer survey that 15% of the dairy farms had dairy manure storage for less than 30 days; 10% of the dairy farms had storage capacities of 60 days, while the remaining operations had 180-day storage capacity. Using a decay rate of 0.375 (Section 3.4.2) for liquid dairy manure, the die-off of fecal coliform in different storage capacities at the ends of the respective storage periods were calculated using Eq. [3.1]. Based on the fractions of different storage capacities, a weighted average die-off was calculated for all dairy manure.

2. Based on fecal coliform die-off, the surviving fraction of fecal coliform at the end of storage period was estimated to be 0.0078 in dairy manure.

3. The annual production of fecal coliform based on 'as-excreted' values (Table 2.4) was calculated for dairy manure.

4. The annual fecal coliform production from dairy manure was multiplied by the fraction of surviving fecal coliform to obtain the amount of fecal coliform that was available for land application on annual basis. For monthly application, the annual figure was multiplied by the fraction of diary applied during that month based on the application schedule given in Table 2.10.

APPENDIX D

Fecal Coliform Loading in Subwatersheds

Table D.1. Monthly nonpoint fecal coliform loadings to the different land use categories in the subwatershed 2301 of the Sheep Creek watershed (Hydrologic Unit L23)

Month	Fecal coliform loadings ($\times 10^8$ cfu/month)					
	Commercial/Industrial	Cropland	Forest	High Density Residential	Rural Residential	Pasture
Jan.	80	135	44,317	624	118,989	3,273,987
Feb.	73	122	40,028	564	107,474	2,957,150
Mar.	80	135	44,317	624	118,989	3,273,987
Apr.	78	130	42,887	604	115,151	3,160,701
May	80	135	44,317	624	118,989	3,258,128
Jun.	78	130	42,887	604	115,151	3,122,332
Jul.	80	135	44,317	624	118,989	3,226,410
Aug.	80	135	44,317	624	118,989	3,226,410
Sep.	78	130	42,887	604	115,151	3,153,027
Oct.	80	135	44,317	624	118,989	3,266,058
Nov.	78	130	42,887	604	115,151	3,168,375
Dec.	80	135	44,317	624	118,989	3,273,987
Total	945	1,587	521,795	7,348	1,401,001	38,360,552

Table D.2. Monthly nonpoint fecal coliform loadings to the different land use categories in the subwatershed 2302 of the Sheep Creek watershed (Hydrologic Unit L23)

Month	Fecal coliform loadings ($\times 10^8$ cfu/month)					
	Commercial/Industrial	Cropland	Forest	High Density Residential	Rural Residential	Pasture
Jan.	24	3,216	21,855	137	46,378	4,833,969
Feb.	21	4,153	19,740	124	41,889	4,366,166
Mar.	24	9,457	21,855	137	46,378	5,045,795
Apr.	23	8,105	21,150	132	44,882	4,911,891
May	24	4,464	21,855	137	46,378	5,063,080
Jun.	23	3,112	21,150	132	44,882	4,854,203
Jul.	24	3,216	21,855	137	46,378	5,012,920
Aug.	24	3,216	21,855	137	46,378	5,014,415
Sep.	23	3,112	21,150	132	44,882	4,904,240
Oct.	24	4,711	21,855	137	46,378	5,075,620
Nov.	23	6,102	21,150	132	44,882	4,883,028
Dec.	24	3,216	21,855	137	46,378	4,833,969
Total	281	56,080	257,325	1,611	546,063	58,799,296

Table D.3. Monthly nonpoint fecal coliform loadings to the different land use categories in the subwatershed 2303 of the Sheep Creek watershed (Hydrologic Unit L23)

Month	Fecal coliform loadings ($\times 10^8$ cfu/month)					
	Commercial/Industrial	Cropland	Forest	High Density Residential	Rural Residential	Pasture
Jan.	18	14	62,600	1,210	51,600	1,848,800
Feb.	16	12	56,500	1,090	46,600	1,664,000
Mar.	18	14	62,600	1,210	51,600	1,848,800
Apr.	18	13	60,600	1,170	49,900	1,787,100
May	18	14	62,600	1,210	51,600	1,838,500
Jun.	18	13	60,600	1,170	49,900	1,756,400
Jul.	18	14	62,600	1,210	51,600	1,818,000
Aug.	18	14	62,600	1,210	51,600	1,818,000
Sep.	18	13	60,600	1,170	49,900	1,776,900
Oct.	18	14	62,600	1,210	51,600	1,838,600
Nov.	18	13	60,600	1,170	49,900	1,787,200
Dec.	18	14	62,600	1,210	51,600	1,848,800
Total	214	162	737,100	14,240	607,400	21,631,100

Table D.4. Monthly nonpoint fecal coliform loadings to the different land use categories in the subwatershed 2304 of the Sheep Creek watershed (Hydrologic Unit L23)

Month	Fecal coliform loadings ($\times 10^8$ cfu/month)					
	Commercial/Industrial	Cropland	Forest	High Density Residential	Rural Residential	Pasture
Jan.	4	0	18,400	374	49,000	1,931,000
Feb.	3	0	16,600	338	44,300	1,748,000
Mar.	4	0	18,400	374	49,000	1,931,000
Apr.	4	0	17,800	362	47,400	1,866,000
May	4	0	18,400	374	49,000	1,930,000
Jun.	4	0	17,800	362	47,400	1,845,000
Jul.	4	0	18,400	374	49,000	1,909,000
Aug.	4	0	18,400	374	49,000	1,909,000
Sep.	4	0	17,800	362	47,400	1,866,000
Oct.	4	0	18,400	374	49,000	1,931,000
Nov.	4	0	17,800	362	47,400	1,867,000
Dec.	4	0	18,400	374	49,000	1,931,000
Total	47	0	216,600	4,404	576,900	22,664,000

Table D.5. Monthly nonpoint fecal coliform loadings to the different land use categories in the subwatershed 2305 of the Sheep Creek watershed (Hydrologic Unit L23)

Month	Fecal coliform loadings ($\times 10^8$ cfu/month)					
	Commercial/Industrial	Cropland	Forest	High Density Residential	Rural Residential	Pasture
Jan.	56	1,290	12,700	397	54,700	1,988,400
Feb.	50	1,160	11,500	359	49,400	1,789,800
Mar.	56	1,290	12,700	397	54,700	1,988,400
Apr.	54	1,250	12,300	384	52,900	1,915,400
May	56	1,290	12,700	397	54,700	1,978,100
Jun.	54	1,250	12,300	384	52,900	1,904,800
Jul.	56	1,290	12,700	397	54,700	1,967,600
Aug.	56	1,290	12,700	397	54,700	1,967,600
Sep.	54	1,250	12,300	384	52,900	1,915,300
Oct.	56	1,290	12,700	397	54,700	1,978,200
Nov.	54	1,250	12,300	384	52,900	1,915,500
Dec.	56	1,290	12,700	397	54,700	1,988,400
Total	658	15,190	149,600	4,674	643,900	23,297,500

Table D.6. Monthly nonpoint fecal coliform loadings to the different land use categories in the subwatershed 2306 of the Sheep Creek watershed (Hydrologic Unit L23)

Month	Fecal coliform loadings ($\times 10^8$ cfu/month)					
	Commercial/Industrial	Cropland	Forest	High Density Residential	Rural Residential	Pasture
Jan.	42	9	25,000	467	98,700	2,697,800
Feb.	38	8	22,500	422	89,100	2,441,200
Mar.	42	9	25,000	467	98,700	2,697,800
Apr.	41	9	24,200	452	95,500	2,615,500
May	42	9	25,000	467	98,700	2,697,500
Jun.	41	9	24,200	452	95,500	2,594,900
Jul.	42	9	25,000	467	98,700	2,677,100
Aug.	42	9	25,000	467	98,700	2,677,100
Sep.	41	9	24,200	452	95,500	2,605,400
Oct.	42	9	25,000	467	98,700	2,697,600
Nov.	41	9	24,200	452	95,500	2,615,600
Dec.	42	9	25,000	467	98,700	2,697,800
Total	496	107	294,300	5,499	1,162,000	31,715,300

Table D.7. Monthly nonpoint fecal coliform loadings to the different land use categories in the subwatershed 2501 of the Elk Creek watershed (Hydrologic Unit L25)

Month	Fecal coliform loadings ($\times 10^8$ cfu/month)					
	Commercial/Industrial	Cropland	Forest	High Density Residential	Rural Residential	Pasture
Jan.	2	0	12,212	35	23,327	1,661,584
Feb.	2	0	11,030	31	21,070	1,500,785
Mar.	2	0	12,212	35	23,327	1,661,584
Apr.	2	0	11,818	34	22,575	1,605,529
May	2	0	12,212	35	23,327	1,656,509
Jun.	2	0	11,818	34	22,575	1,593,250
Jul.	2	0	12,212	35	23,327	1,646,358
Aug.	2	0	12,212	35	23,327	1,646,358
Sep.	2	0	11,818	34	22,575	1,603,073
Oct.	2	0	12,212	35	23,327	1,659,046
Nov.	2	0	11,818	34	22,575	1,607,984
Dec.	2	0	12,212	35	23,327	1,661,584
Total	24	0	143,786	412	274,659	19,503,644

Table D.8. Monthly nonpoint fecal coliform loadings to the different land use categories in the subwatershed 2502 of the Elk Creek watershed (Hydrologic Unit L25)

Month	Fecal coliform loadings ($\times 10^8$ cfu/month)					
	Commercial/Industrial	Cropland	Forest	High Density Residential	Rural Residential	Pasture
Jan.	0	0	24,836	10	11,342	1,648,476
Feb.	0	0	22,433	9	10,244	1,488,946
Mar.	0	0	24,836	10	11,342	1,648,476
Apr.	0	0	24,035	10	10,976	1,592,330
May	0	0	24,836	10	11,342	1,642,338
Jun.	0	0	24,035	10	10,976	1,577,480
Jul.	0	0	24,836	10	11,342	1,630,062
Aug.	0	0	24,836	10	11,342	1,630,062
Sep.	0	0	24,035	10	10,976	1,589,360
Oct.	0	0	24,836	10	11,342	1,645,407
Nov.	0	0	24,035	10	10,976	1,595,300
Dec.	0	0	24,836	10	11,342	1,648,476
Total	0	0	292,425	119	133,542	19,336,713

Table D.9. Monthly nonpoint fecal coliform loadings to the different land use categories in the subwatershed 2503 of the Elk Creek watershed (Hydrologic Unit L25)

Month	Fecal coliform loadings ($\times 10^8$ cfu/month)					
	Commercial/Industrial	Cropland	Forest	High Density Residential	Rural Residential	Pasture
Jan.	332	1,263	45,108	3,098	366,975	9,532,068
Feb.	300	1,621	40,743	2,798	331,461	8,609,610
Mar.	332	3,668	45,108	3,098	366,975	9,613,961
Apr.	321	3,146	43,653	2,998	355,137	9,312,136
May	332	1,744	45,108	3,098	366,975	9,614,742
Jun.	321	1,222	43,653	2,998	355,137	9,275,552
Jul.	332	1,263	45,108	3,098	366,975	9,583,547
Aug.	332	1,263	45,108	3,098	366,975	9,584,123
Sep.	321	1,222	43,653	2,998	355,137	9,306,317
Oct.	332	1,839	45,108	3,098	366,975	9,622,541
Nov.	321	2,374	43,653	2,998	355,137	9,303,833
Dec.	332	1,263	45,108	3,098	366,975	9,532,068
Total	3,908	21,888	531,111	36,476	4,320,834	112,890,498

Table D.10. Monthly nonpoint fecal coliform loadings to the different land use categories in the subwatershed 2504 of the Elk Creek watershed (Hydrologic Unit L25)

Month	Fecal coliform loadings ($\times 10^8$ cfu/month)					
	Commercial/Industrial	Cropland	Forest	High Density Residential	Rural Residential	Pasture
Jan.	149	399	21,044	531	70,630	3,996,253
Feb.	135	1,323	19,007	479	63,795	3,609,519
Mar.	149	5,209	21,044	531	70,630	4,159,905
Apr.	145	4,234	20,365	514	68,351	4,052,448
May	149	1,361	21,044	531	70,630	4,182,424
Jun.	145	387	20,365	514	68,351	4,030,047
Jul.	149	399	21,044	531	70,630	4,162,001
Aug.	149	399	21,044	531	70,630	4,163,153
Sep.	145	387	20,365	514	68,351	4,050,963
Oct.	149	1,552	21,044	531	70,630	4,187,530
Nov.	145	2,691	20,365	514	68,351	4,025,715
Dec.	149	399	21,044	531	70,630	3,996,253
Total	1,758	18,740	247,775	6,252	831,609	48,616,211

Table D.11. Monthly nonpoint fecal coliform loadings to the different land use categories in the subwatershed 2505 of the Elk Creek watershed (Hydrologic Unit L25)

Month	Fecal coliform loadings ($\times 10^8$ cfu/month)					
	Commercial/Industrial	Cropland	Forest	High Density Residential	Rural Residential	Pasture
Jan.	23	0	10,036	188	28,961	645,018
Feb.	20	0	9,065	170	26,158	582,597
Mar.	23	0	10,036	188	28,961	645,018
Apr.	22	0	9,713	182	28,027	623,198
May	23	0	10,036	188	28,961	642,924
Jun.	22	0	9,713	182	28,027	618,130
Jul.	23	0	10,036	188	28,961	638,735
Aug.	23	0	10,036	188	28,961	638,735
Sep.	22	0	9,713	182	28,027	622,184
Oct.	23	0	10,036	188	28,961	643,971
Nov.	22	0	9,713	182	28,027	624,211
Dec.	23	0	10,036	188	28,961	645,018
Total	269	0	118,169	2,214	340,993	7,569,739

Table D.12. Monthly nonpoint fecal coliform loadings to the different land use categories in the subwatershed 2506 of the Elk Creek watershed (Hydrologic Unit L25)

Month	Fecal coliform loadings ($\times 10^8$ cfu/month)					
	Commercial/Industrial	Cropland	Forest	High Density Residential	Rural Residential	Pasture
Jan.	222	645	45,197	110	150,508	6,514,193
Feb.	201	583	40,823	100	135,943	5,883,788
Mar.	222	645	45,197	110	150,508	6,514,193
Apr.	215	624	43,739	107	145,653	6,295,204
May	222	645	45,197	110	150,508	6,495,894
Jun.	215	624	43,739	107	145,653	6,250,932
Jul.	222	645	45,197	110	150,508	6,459,297
Aug.	222	645	45,197	110	150,508	6,459,297
Sep.	215	624	43,739	107	145,653	6,286,349
Oct.	222	645	45,197	110	150,508	6,505,044
Nov.	215	624	43,739	107	145,653	6,304,058
Dec.	222	645	45,197	110	150,508	6,514,193
Total	2,615	7,594	532,158	1,298	1,772,111	76,482,442

Table D.13. Monthly nonpoint fecal coliform loadings to the different land use categories in the subwatershed 2507 of the Elk Creek watershed (Hydrologic Unit L25)

Month	Fecal coliform loadings ($\times 10^8$ cfu/month)					
	Commercial/Industrial	Cropland	Forest	High Density Residential	Rural Residential	Pasture
Jan.	55	55	11,114	260	57,809	923,476
Feb.	50	50	10,038	235	52,215	834,107
Mar.	55	55	11,114	260	57,809	923,476
Apr.	54	54	10,755	251	55,945	892,907
May	55	55	11,114	260	57,809	921,865
Jun.	54	54	10,755	251	55,945	889,009
Jul.	55	55	11,114	260	57,809	918,642
Aug.	55	55	11,114	260	57,809	918,642
Sep.	54	54	10,755	251	55,945	892,127
Oct.	55	55	11,114	260	57,809	922,670
Nov.	54	54	10,755	251	55,945	893,686
Dec.	55	55	11,114	260	57,809	923,476
Total	651	651	130,856	3,059	680,658	10,854,083

Table D.14. Monthly nonpoint fecal coliform loadings to the different land use categories in the subwatershed 2508 of the Elk Creek watershed (Hydrologic Unit L25)

Month	Fecal coliform loadings ($\times 10^8$ cfu/month)					
	Commercial/Industrial	Cropland	Forest	High Density Residential	Rural Residential	Pasture
Jan.	181	1,441	45,852	635	285,409	11,494,119
Feb.	163	1,301	41,415	574	257,789	10,381,785
Mar.	181	1,441	45,852	635	285,409	11,494,119
Apr.	175	1,394	44,373	615	276,203	11,106,212
May	181	1,441	45,852	635	285,409	11,458,720
Jun.	175	1,394	44,373	615	276,203	11,020,568
Jul.	181	1,441	45,852	635	285,409	11,387,920
Aug.	181	1,441	45,852	635	285,409	11,387,920
Sep.	175	1,394	44,373	615	276,203	11,089,083
Oct.	181	1,441	45,852	635	285,409	11,476,419
Nov.	175	1,394	44,373	615	276,203	11,123,341
Dec.	181	1,441	45,852	635	285,409	11,494,119
Total	2,130	16,964	539,871	7,479	3,360,464	134,914,325

Table D.15. Monthly nonpoint fecal coliform loadings to the different land use categories in the subwatershed 26a01 of the Machine Creek watershed (Hydrologic Unit L26a)

Month	Fecal coliform loadings ($\times 10^8$ cfu/month)					
	Commercial/Industrial	Cropland	Forest	High Density Residential	Rural Residential	Pasture
Jan.	31	825	11,843	27,048	68,680	2,153,007
Feb.	28	745	10,697	24,430	62,034	1,944,651
Mar.	31	825	11,843	27,048	68,680	2,153,007
Apr.	30	798	11,461	26,175	66,465	2,080,111
May	31	825	11,843	27,048	68,680	2,145,890
Jun.	30	798	11,461	26,175	66,465	2,062,895
Jul.	31	825	11,843	27,048	68,680	2,131,658
Aug.	31	825	11,843	27,048	68,680	2,131,658
Sep.	30	798	11,461	26,175	66,465	2,076,668
Oct.	31	825	11,843	27,048	68,680	2,149,448
Nov.	30	798	11,461	26,175	66,465	2,083,555
Dec.	31	825	11,843	27,048	68,680	2,153,007
Total	365	9,712	139,442	318,466	808,654	25,265,555

Table D.16. Monthly nonpoint fecal coliform loadings to the different land use categories in the subwatershed 26a02 of the Machine Creek watershed (Hydrologic Unit L26a)

Month	Fecal coliform loadings ($\times 10^8$ cfu/month)					
	Commercial/Industrial	Cropland	Forest	High Density Residential	Rural Residential	Pasture
Jan.	12	3,177	13,625	279	59,010	2,874,402
Feb.	11	2,869	12,306	252	53,299	2,596,234
Mar.	12	3,177	13,625	279	59,010	2,874,402
Apr.	12	3,074	13,185	270	57,106	2,778,128
May	12	3,177	13,625	279	59,010	2,867,105
Jun.	12	3,074	13,185	270	57,106	2,760,370
Jul.	12	3,177	13,625	279	59,010	2,852,408
Aug.	12	3,177	13,625	279	59,010	2,852,382
Sep.	12	3,074	13,185	270	57,106	2,774,576
Oct.	12	3,177	13,625	279	59,010	2,870,732
Nov.	12	3,074	13,185	270	57,106	2,781,679
Dec.	12	3,177	13,625	279	59,010	2,874,406
Total	143	37,404	160,421	3,285	694,793	33,756,824

Table D.17. Monthly nonpoint fecal coliform loadings to the different land use categories in the subwatershed 26a03 of the Machine Creek watershed (Hydrologic Unit L26a)

Month	Fecal coliform loadings ($\times 10^8$ cfu/month)					
	Commercial/Industrial	Cropland	Forest	High Density Residential	Rural Residential	Pasture
Jan.	51	544	7,119	134	22,811	1,781,550
Feb.	46	491	6,430	121	20,604	1,609,142
Mar.	51	544	7,119	134	22,811	1,781,550
Apr.	50	526	6,890	130	22,075	1,719,631
May	51	544	7,119	134	22,811	1,772,343
Jun.	50	526	6,890	130	22,075	1,697,312
Jul.	51	544	7,119	134	22,811	1,753,849
Aug.	51	544	7,119	134	22,811	1,753,849
Sep.	50	526	6,890	130	22,075	1,715,145
Oct.	51	544	7,119	134	22,811	1,776,933
Nov.	50	526	6,890	130	22,075	1,724,081
Dec.	51	544	7,119	134	22,811	1,781,554
Total	603	6,403	83,823	1,579	268,581	20,866,939

Table D.18. Monthly nonpoint fecal coliform loadings to the different land use categories in the subwatershed 26a04 of the Machine Creek watershed (Hydrologic Unit L26a)

Month	Fecal coliform loadings ($\times 10^8$ cfu/month)					
	Commercial/Industrial	Cropland	Forest	High Density Residential	Rural Residential	Pasture
Jan.	0	583	11,055	344	63,142	3,833,322
Feb.	0	527	9,985	311	57,032	3,462,355
Mar.	0	583	11,055	344	63,142	3,833,322
Apr.	0	564	10,698	333	61,105	3,701,451
May	0	583	11,055	344	63,142	3,816,344
Jun.	0	564	10,698	333	61,105	3,660,483
Jul.	0	583	11,055	344	63,142	3,782,551
Aug.	0	583	11,055	344	63,142	3,782,455
Sep.	0	564	10,698	333	61,105	3,693,236
Oct.	0	583	11,055	344	63,142	3,824,833
Nov.	0	564	10,698	333	61,105	3,709,666
Dec.	0	583	11,055	344	63,142	3,833,322
Total	0	6,864	130,162	4,051	743,446	44,933,340

Table D.19. Monthly nonpoint fecal coliform loadings to the different land use categories in the subwatershed 26a05 of the Machine Creek watershed (Hydrologic Unit L26a)

Month	Fecal coliform loadings ($\times 10^8$ cfu/month)					
	Commercial/Industrial	Cropland	Forest	High Density Residential	Rural Residential	Pasture
Jan.	16	575	9,423	140	61,189	1,912,297
Feb.	15	519	8,511	126	55,268	1,727,236
Mar.	16	575	9,423	140	61,189	1,912,297
Apr.	16	557	9,119	135	59,215	1,847,560
May	16	575	9,423	140	61,189	1,905,994
Jun.	16	557	9,119	135	59,215	1,905,190
Jul.	16	575	9,423	140	61,189	2,004,152
Aug.	16	575	9,423	140	61,189	1,938,880
Sep.	16	557	9,119	135	59,215	1,844,510
Oct.	16	575	9,423	140	61,189	1,909,145
Nov.	16	557	9,119	135	59,215	1,850,610
Dec.	16	575	9,423	140	61,189	1,912,297
Total	191	6,772	110,948	1,646	720,451	22,670,168

Table D.20. Monthly nonpoint fecal coliform loadings to the different land use categories in the subwatershed 26a06 of the Machine Creek watershed (Hydrologic Unit L26a)

Month	Fecal coliform loadings ($\times 10^8$ cfu/month)					
	Commercial/Industrial	Cropland	Forest	High Density Residential	Rural Residential	Pasture
Jan.	0	902	7,456	204	31,285	1,386,313
Feb.	0	814	6,734	184	28,258	1,252,154
Mar.	0	902	7,456	204	31,285	1,386,313
Apr.	0	873	7,215	198	30,276	1,339,547
May	0	902	7,456	204	31,285	1,382,084
Jun.	0	873	7,215	198	30,276	1,329,314
Jul.	0	902	7,456	204	31,285	1,373,625
Aug.	0	902	7,456	204	31,285	1,373,625
Sep.	0	873	7,215	198	30,276	1,337,500
Oct.	0	902	7,456	204	31,285	1,384,199
Nov.	0	873	7,215	198	30,276	1,341,593
Dec.	0	902	7,456	204	31,285	1,386,313
Total	0	10,620	87,786	2,404	368,357	16,272,580

Table D.21. Monthly nonpoint fecal coliform loadings to the different land use categories in the subwatershed 26a07 of the Machine Creek watershed (Hydrologic Unit L26a)

Month	Fecal coliform loadings ($\times 10^8$ cfu/month)					
	Commercial/Industrial	Cropland	Forest	High Density Residential	Rural Residential	Pasture
Jan.	0	2,188	6,855	20	4,734	554,716
Feb.	0	1,976	6,191	18	4,276	501,034
Mar.	0	2,188	6,855	20	4,734	554,716
Apr.	0	2,117	6,634	19	4,581	536,261
May	0	2,188	6,855	20	4,734	553,556
Jun.	0	2,117	6,634	19	4,581	533,454
Jul.	0	2,188	6,855	20	4,734	551,236
Aug.	0	2,188	6,855	20	4,734	551,236
Sep.	0	2,117	6,634	19	4,581	535,699
Oct.	0	2,188	6,855	20	4,734	554,136
Nov.	0	2,117	6,634	19	4,581	536,822
Dec.	0	2,188	6,855	20	4,734	554,716
Total	0	25,760	80,712	234	55,738	6,517,582

Table D.22. Monthly nonpoint fecal coliform loadings to the different land use categories in the subwatershed 26a08 of the Machine Creek watershed (Hydrologic Unit L26a)

Month	Fecal coliform loadings ($\times 10^8$ cfu/month)					
	Commercial/Industrial	Cropland	Forest	High Density Residential	Rural Residential	Pasture
Jan.	13	3,663	4,326	112	39,942	503,186
Feb.	12	3,308	3,907	101	36,077	454,491
Mar.	13	3,663	4,326	112	39,942	503,186
Apr.	13	3,545	4,186	108	38,654	486,357
May	13	3,663	4,326	112	39,942	501,952
Jun.	13	3,545	4,186	108	38,654	483,371
Jul.	13	3,663	4,326	112	39,942	499,483
Aug.	13	3,663	4,326	112	39,942	499,483
Sep.	13	3,545	4,186	108	38,654	485,760
Oct.	13	3,663	4,326	112	39,942	502,569
Nov.	13	3,545	4,186	108	38,654	486,954
Dec.	13	3,663	4,326	112	39,942	503,186
Total	155	43,129	50,933	1,317	470,287	5,909,978

Table D.23. Monthly nonpoint fecal coliform loadings to the different land use categories in the subwatershed 26b01 of the Little Otter River watershed (Hydrologic Unit L26b)

Month	Fecal coliform loadings ($\times 10^8$ cfu/month)					
	Commercial/Industrial	Cropland	Forest	High Density Residential	Rural Residential	Pasture
Jan.	100	963	17,218	18,207	222,403	6,384,339
Feb.	90	1,639	15,551	16,445	200,880	5,766,499
Mar.	100	4,811	17,218	18,207	222,403	6,515,083
Apr.	96	4,010	16,662	17,619	215,229	6,318,249
May	100	1,733	17,218	18,207	222,403	6,516,483
Jun.	96	932	16,662	17,619	215,229	6,260,214
Jul.	100	963	17,218	18,207	222,403	6,466,983
Aug.	100	963	17,218	18,207	222,403	6,467,905
Sep.	96	932	16,662	17,619	215,229	6,309,038
Oct.	100	1,885	17,218	18,207	222,403	6,528,857
Nov.	96	2,775	16,662	17,619	215,229	6,304,919
Dec.	100	963	17,218	18,207	222,403	6,384,339
Total	1,174	22,569	202,725	214,370	2,618,617	76,222,908

Table D.24. Monthly nonpoint fecal coliform loadings to the different land use categories in the subwatershed 26b02 of the Little Otter River watershed (Hydrologic Unit L26b)

Month	Fecal coliform loadings ($\times 10^8$ cfu/month)					
	Commercial/Industrial	Cropland	Forest	High Density Residential	Rural Residential	Pasture
Jan.	197	496	9,032	185,174	32,987	1,394,602
Feb.	178	448	8,158	167,254	29,795	1,259,641
Mar.	197	496	9,032	185,174	32,987	1,394,602
Apr.	191	480	8,741	179,201	31,923	1,347,362
May	197	496	9,032	185,174	32,987	1,389,946
Jun.	191	480	8,741	179,201	31,923	1,336,096
Jul.	197	496	9,032	185,174	32,987	1,380,633
Aug.	197	496	9,032	185,174	32,987	1,380,633
Sep.	191	480	8,741	179,201	31,923	1,345,109
Oct.	197	496	9,032	185,174	32,987	1,392,274
Nov.	191	480	8,741	179,201	31,923	1,349,615
Dec.	197	496	9,032	185,174	32,987	1,394,602
Total	2,321	5,840	106,346	2,180,276	388,396	16,365,115

Table D.25. Monthly nonpoint fecal coliform loadings to the different land use categories in the subwatershed 26b03 of the Little Otter River watershed (Hydrologic Unit L26b)

Month	Fecal coliform loadings ($\times 10^8$ cfu/month)					
	Commercial/Industrial	Cropland	Forest	High Density Residential	Rural Residential	Pasture
Jan.	66	70	27,305	82,345	206,033	4,093,116
Feb.	60	64	24,663	74,376	186,094	3,697,008
Mar.	66	70	27,305	82,345	206,033	4,093,116
Apr.	64	68	26,425	79,689	199,387	3,956,781
May	66	70	27,305	82,345	206,033	4,084,230
Jun.	64	68	26,425	79,689	199,387	3,935,282
Jul.	66	70	27,305	82,345	206,033	4,066,458
Aug.	66	70	27,305	82,345	206,033	4,066,458
Sep.	64	68	26,425	79,689	199,387	3,952,481
Oct.	66	70	27,305	82,345	206,033	4,088,673
Nov.	64	68	26,425	79,689	199,387	3,961,080
Dec.	66	70	27,305	82,345	206,033	4,093,116
Total	778	826	321,498	969,547	2,425,873	48,087,799

Table D.26. Monthly nonpoint fecal coliform loadings to the different land use categories in the subwatershed 26b04 of the Little Otter River watershed (Hydrologic Unit L26b)

Month	Fecal coliform loadings ($\times 10^8$ cfu/month)					
	Commercial/Industrial	Cropland	Forest	High Density Residential	Rural Residential	Pasture
Jan.	187	157	11,559	122,793	51,960	462,784
Feb.	169	142	10,440	110,909	46,932	417,998
Mar.	187	157	11,559	122,793	51,960	462,784
Apr.	181	152	11,186	118,832	50,284	447,047
May	187	157	11,559	122,793	51,960	461,112
Jun.	181	152	11,186	118,832	50,284	443,002
Jul.	187	157	11,559	122,793	51,960	457,769
Aug.	187	157	11,559	122,793	51,960	457,769
Sep.	181	152	11,186	118,832	50,284	446,238
Oct.	187	157	11,559	122,793	51,960	461,948
Nov.	181	152	11,186	118,832	50,284	447,855
Dec.	187	157	11,559	122,793	51,960	462,784
Total	2,202	1,849	136,097	1,445,788	611,788	5,429,090

Table D.27. Monthly nonpoint fecal coliform loadings to the different land use categories in the subwatershed 26b05 of the Little Otter River watershed (Hydrologic Unit L26b)

Month	Fecal coliform loadings ($\times 10^8$ cfu/month)					
	Commercial/Industrial	Cropland	Forest	High Density Residential	Rural Residential	Pasture
Jan.	68	794	8,937	17,783	43,081	1,442,388
Feb.	62	717	8,072	16,062	38,912	1,302,802
Mar.	68	794	8,937	17,783	43,081	1,442,388
Apr.	66	768	8,649	17,209	41,691	1,394,345
May	68	794	8,937	17,783	43,081	1,439,259
Jun.	66	768	8,649	17,209	41,691	1,386,774
Jul.	68	794	8,937	17,783	43,081	1,433,000
Aug.	68	794	8,937	17,783	43,081	1,433,000
Sep.	66	768	8,649	17,209	41,691	1,392,831
Oct.	68	794	8,937	17,783	43,081	1,440,823
Nov.	66	768	8,649	17,209	41,691	1,395,859
Dec.	68	794	8,937	17,783	43,081	1,442,388
Total	802	9,347	105,227	209,379	507,243	16,945,857

Table D.28. Monthly nonpoint fecal coliform loadings to the different land use categories in the subwatershed 26b06 of the Little Otter River watershed (Hydrologic Unit L26b)

Month	Fecal coliform loadings ($\times 10^8$ cfu/month)					
	Commercial/Industrial	Cropland	Forest	High Density Residential	Rural Residential	Pasture
Jan.	69	0	12,667	435	75,272	1,338,987
Feb.	62	0	11,442	392	67,988	1,209,408
Mar.	69	0	12,667	435	75,272	1,338,987
Apr.	66	0	12,259	421	72,844	1,294,453
May	69	0	12,667	435	75,272	1,336,217
Jun.	66	0	12,259	421	72,844	1,287,752
Jul.	69	0	12,667	435	75,272	1,330,677
Aug.	69	0	12,667	435	75,272	1,330,677
Sep.	66	0	12,259	421	72,844	1,293,113
Oct.	69	0	12,667	435	75,272	1,337,602
Nov.	66	0	12,259	421	72,844	1,295,794
Dec.	69	0	12,667	435	75,272	1,338,987
Total	809	0	149,147	5,121	886,268	15,732,654

Table D.29. Monthly nonpoint fecal coliform loadings to the different land use categories in the subwatershed 26b07 of the Little Otter River watershed (Hydrologic Unit L26b)

Month	Fecal coliform loadings ($\times 10^8$ cfu/month)					
	Commercial/Industrial	Cropland	Forest	High Density Residential	Rural Residential	Pasture
Jan.	57	112	8,700	365	30,991	786,046
Feb.	51	101	7,859	330	27,992	709,977
Mar.	57	112	8,700	365	30,991	786,046
Apr.	55	108	8,420	353	29,991	760,002
May	57	112	8,700	365	30,991	784,625
Jun.	55	108	8,420	353	29,991	756,564
Jul.	57	112	8,700	365	30,991	781,783
Aug.	57	112	8,700	365	30,991	781,783
Sep.	55	108	8,420	353	29,991	759,314
Oct.	57	112	8,700	365	30,991	785,335
Nov.	55	108	8,420	353	29,991	760,689
Dec.	57	112	8,700	365	30,991	786,046
Total	670	1,317	102,439	4,297	364,893	9,238,210

Table D.30. Monthly nonpoint fecal coliform loadings to the different land use categories in the subwatershed 26b08 of the Little Otter River watershed (Hydrologic Unit L26b)

Month	Fecal coliform loadings ($\times 10^8$ cfu/month)					
	Commercial/Industrial	Cropland	Forest	High Density Residential	Rural Residential	Pasture
Jan.	7	799	13,661	83	20,867	292,729
Feb.	7	914	12,339	75	18,848	264,400
Mar.	7	1,761	13,661	83	20,867	325,468
Apr.	7	1,543	13,221	80	20,194	320,962
May	7	991	13,661	83	20,867	331,306
Jun.	7	773	13,221	80	20,194	319,705
Jul.	7	799	13,661	83	20,867	329,886
Aug.	7	799	13,661	83	20,867	330,120
Sep.	7	773	13,221	80	20,194	321,319
Oct.	7	1,029	13,661	83	20,867	331,661
Nov.	7	1,234	13,221	80	20,194	314,969
Dec.	7	799	13,661	83	20,867	292,729
Total	84	12,214	160,850	976	245,693	3,775,254

Table D.31. Monthly nonpoint fecal coliform loadings to the different land use categories in the subwatershed 26b09 of the Little Otter River watershed (Hydrologic Unit L26b)

Month	Fecal coliform loadings ($\times 10^8$ cfu/month)					
	Commercial/Industrial	Cropland	Forest	High Density Residential	Rural Residential	Pasture
Jan.	0	175	6,858	17	20,509	897,252
Feb.	0	158	6,194	16	18,524	810,422
Mar.	0	175	6,858	17	20,509	897,252
Apr.	0	170	6,637	17	19,847	867,860
May	0	175	6,858	17	20,509	896,326
Jun.	0	170	6,637	17	19,847	865,619
Jul.	0	175	6,858	17	20,509	894,473
Aug.	0	175	6,858	17	20,509	894,473
Sep.	0	170	6,637	17	19,847	867,412
Oct.	0	175	6,858	17	20,509	896,789
Nov.	0	170	6,637	17	19,847	868,309
Dec.	0	175	6,858	17	20,509	897,252
Total	0	2,063	80,748	203	241,475	10,553,439

Table D.32. Monthly nonpoint fecal coliform loadings to the different land use categories in the subwatershed 2801 of the Lower Big Otter River watershed (Hydrologic Unit L28)

Month	Fecal coliform loadings ($\times 10^8$ cfu/month)					
	Commercial/Industrial	Cropland	Forest	High Density Residential	Rural Residential	Pasture
Jan.	10	1	26,384	66	37,574	1,653,638
Feb.	9	1	23,831	60	33,938	1,493,608
Mar.	10	1	26,384	66	37,574	1,653,638
Apr.	10	1	25,533	64	36,362	1,598,352
May	10	1	26,384	66	37,574	1,649,623
Jun.	10	1	25,533	64	36,362	1,588,639
Jul.	10	1	26,384	66	37,574	1,641,594
Aug.	10	1	26,384	66	37,574	1,641,594
Sep.	10	1	25,533	64	36,362	1,596,410
Oct.	10	1	26,384	66	37,574	1,651,631
Nov.	10	1	25,533	64	36,362	1,600,295
Dec.	10	1	26,384	66	37,574	1,653,638
Total	119	10	310,651	778	442,406	19,422,659

Table D.33. Monthly nonpoint fecal coliform loadings to the different land use categories in the subwatershed 2802 of the Lower Big Otter River watershed (Hydrologic Unit L28)

Month	Fecal coliform loadings ($\times 10^8$ cfu/month)					
	Commercial/Industrial	Cropland	Forest	High Density Residential	Rural Residential	Pasture
Jan.	0	487	3,256	4	9,805	1,444,431
Feb.	0	440	2,941	3	8,856	1,304,647
Mar.	0	487	3,256	4	9,805	1,444,431
Apr.	0	471	3,151	3	9,488	1,395,307
May	0	487	3,256	4	9,805	1,439,202
Jun.	0	471	3,151	3	9,488	1,382,656
Jul.	0	487	3,256	4	9,805	1,428,745
Aug.	0	487	3,256	4	9,805	1,428,745
Sep.	0	471	3,151	3	9,488	1,392,777
Oct.	0	487	3,256	4	9,805	1,441,817
Nov.	0	471	3,151	3	9,488	1,397,837
Dec.	0	487	3,256	4	9,805	1,444,431
Total	0	5,733	38,337	43	115,443	16,945,026

Table D.34. Monthly nonpoint fecal coliform loadings to the different land use categories in the subwatershed 2803 of the Lower Big Otter River watershed (Hydrologic Unit L28)

Month	Fecal coliform loadings ($\times 10^8$ cfu/month)					
	Commercial/Industrial	Cropland	Forest	High Density Residential	Rural Residential	Pasture
Jan.	21	121	16,416	100	32,364	1,270,433
Feb.	19	110	14,827	90	29,232	1,147,488
Mar.	21	121	16,416	100	32,364	1,270,433
Apr.	20	117	15,886	97	31,320	1,226,881
May	21	121	16,416	100	32,364	1,265,121
Jun.	20	117	15,886	97	31,320	1,214,029
Jul.	21	121	16,416	100	32,364	1,254,497
Aug.	21	121	16,416	100	32,364	1,254,497
Sep.	20	117	15,886	97	31,320	1,224,310
Oct.	21	121	16,416	100	32,364	1,267,777
Nov.	20	117	15,886	97	31,320	1,229,451
Dec.	21	121	16,416	100	32,364	1,270,433
Total	246	1,425	193,283	1,178	381,060	14,895,350

Table D.35. Monthly nonpoint fecal coliform loadings to the different land use categories in the subwatershed 2804 of the Lower Big Otter River watershed (Hydrologic Unit L28)

Month	Fecal coliform loadings ($\times 10^8$ cfu/month)					
	Commercial/Industrial	Cropland	Forest	High Density Residential	Rural Residential	Pasture
Jan.	91	118	4,803	236	73,725	748,265
Feb.	82	107	4,338	214	66,590	675,852
Mar.	91	118	4,803	236	73,725	748,265
Apr.	88	114	4,648	229	71,346	722,547
May	91	118	4,803	236	73,725	744,998
Jun.	88	114	4,648	229	71,346	714,642
Jul.	91	118	4,803	236	73,725	738,464
Aug.	91	118	4,803	236	73,725	738,464
Sep.	88	114	4,648	229	71,346	720,966
Oct.	91	118	4,803	236	73,725	746,632
Nov.	88	114	4,648	229	71,346	724,128
Dec.	91	118	4,803	236	73,725	748,265
Total	1,071	1,389	56,551	2,782	868,049	8,771,488

Table D.36. Monthly nonpoint fecal coliform loadings to the different land use categories in the subwatershed 2805 of the Lower Big Otter River watershed (Hydrologic Unit L28)

Month	Fecal coliform loadings ($\times 10^8$ cfu/month)					
	Commercial/Industrial	Cropland	Forest	High Density Residential	Rural Residential	Pasture
Jan.	73	443	38,148	2,325	257,345	3,159,540
Feb.	66	1,170	34,456	2,100	232,441	2,853,778
Mar.	73	4,291	38,148	2,325	257,345	3,290,388
Apr.	71	3,507	36,917	2,250	249,044	3,204,766
May	73	1,213	38,148	2,325	257,345	3,306,626
Jun.	71	429	36,917	2,250	249,044	3,182,581
Jul.	73	443	38,148	2,325	257,345	3,286,762
Aug.	73	443	38,148	2,325	257,345	3,287,684
Sep.	71	429	36,917	2,250	249,044	3,202,726
Oct.	73	1,365	38,148	2,325	257,345	3,311,592
Nov.	71	2,272	36,917	2,250	249,044	3,184,247
Dec.	73	443	38,148	2,325	257,345	3,159,540
Total	861	16,448	449,160	27,375	3,030,032	38,430,230

Table D.37. Monthly nonpoint fecal coliform loadings to the different land use categories in the subwatershed 2806 of the Lower Big Otter River watershed (Hydrologic Unit L28)

Month	Fecal coliform loadings ($\times 10^8$ cfu/month)					
	Commercial/Industrial	Cropland	Forest	High Density Residential	Rural Residential	Pasture
Jan.	209	1,621	55,819	1,024	150,142	2,768,971
Feb.	189	1,464	50,417	925	135,612	2,501,006
Mar.	209	1,621	55,819	1,024	150,142	2,768,971
Apr.	203	1,569	54,019	991	145,299	2,676,559
May	209	1,621	55,819	1,024	150,142	2,762,584
Jun.	203	1,569	54,019	991	145,299	2,661,106
Jul.	209	1,621	55,819	1,024	150,142	2,749,810
Aug.	209	1,621	55,819	1,024	150,142	2,749,810
Sep.	203	1,569	54,019	991	145,299	2,673,469
Oct.	209	1,621	55,819	1,024	150,142	2,765,778
Nov.	203	1,569	54,019	991	145,299	2,679,650
Dec.	209	1,621	55,819	1,024	150,142	2,768,971
Total	2,464	19,087	657,226	12,057	1,767,802	32,526,685

Table D.38. Monthly nonpoint fecal coliform loadings to the different land use categories in the subwatershed 2807 of the Lower Big Otter River watershed (Hydrologic Unit L28)

Month	Fecal coliform loadings ($\times 10^8$ cfu/month)					
	Commercial/Industrial	Cropland	Forest	High Density Residential	Rural Residential	Pasture
Jan.	0	3,348	16,426	51	17,070	819,411
Feb.	0	3,024	14,837	46	15,419	740,113
Mar.	0	3,348	16,426	51	17,070	819,411
Apr.	0	3,240	15,897	50	16,520	792,063
May	0	3,348	16,426	51	17,070	817,518
Jun.	0	3,240	15,897	50	16,520	787,484
Jul.	0	3,348	16,426	51	17,070	813,733
Aug.	0	3,348	16,426	51	17,070	813,733
Sep.	0	3,240	15,897	50	16,520	791,147
Oct.	0	3,348	16,426	51	17,070	818,465
Nov.	0	3,240	15,897	50	16,520	792,978
Dec.	0	3,348	16,426	51	17,070	819,411
Total	0	39,420	193,407	603	200,989	9,625,467

Table D.39. Monthly nonpoint fecal coliform loadings to the different land use categories in the subwatershed 2808 of the Lower Big Otter River watershed (Hydrologic Unit L28)

Month	Fecal coliform loadings ($\times 10^8$ cfu/month)					
	Commercial/Industrial	Cropland	Forest	High Density Residential	Rural Residential	Pasture
Jan.	69	2,003	7,418	43	13,319	1,136,527
Feb.	63	1,809	6,700	39	12,030	1,026,540
Mar.	69	2,003	7,418	43	13,319	1,136,527
Apr.	67	1,939	7,179	41	12,890	1,097,598
May	69	2,003	7,418	43	13,319	1,131,843
Jun.	67	1,939	7,179	41	12,890	1,086,266
Jul.	69	2,003	7,418	43	13,319	1,122,475
Aug.	69	2,003	7,418	43	13,319	1,122,475
Sep.	67	1,939	7,179	41	12,890	1,095,332
Oct.	69	2,003	7,418	43	13,319	1,134,185
Nov.	67	1,939	7,179	41	12,890	1,099,865
Dec.	69	2,003	7,418	43	13,319	1,136,527
Total	814	23,586	87,342	504	156,823	13,326,160

APPENDIX E.

Required Reductions in Fecal Coliform Loads by Subwatershed – Allocation Scenario

Table E.1a.Required annual reductions in nonpoint sources in subwatershed 2301 of the Sheep Creek watershed (Hydrologic Unit L23)

Land use	Current conditions load (x 10^8 cfu)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu)	Percent reduction
Commercial/ Industrial	5.91	<0.1	5.91	0
Cropland	5.70	<0.1	2.28	60
Forest	293797.44	3.2	293797.44	0
High Density Residential	209.61	<0.1	209.61	0
Rural Residential	84593.37	0.9	84593.37	0
Pasture	8856849.00	95.9	3542739.60	60
Total	9235461.03	100.0	3951348.21	N/A

Table E.1b. Required annual reductions in direct nonpoint sources in subwatershed 2301 of the Sheep Creek watershed (Hydrologic Unit L23)

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent reduction
Cattle in stream	374,734	66.08	0	100.00
Wildlife in stream	121,196	21.37	24,239	80.00
Straight pipes	71,175	12.55	0	100.00
Total	567,105	100.00	24,239	95.73

Table E.2a.Required annual reductions in nonpoint sources in subwatershed 2302 of the Sheep Creek watershed (Hydrologic Unit L23)

Land use	Current conditions load (x 10^8 cfu)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu)	Percent reduction
Commercial/ Industrial	0.51	<0.1	0.51	0
Cropland	10687.54	<0.1	4275.02	60
Forest	63034.13	0.2	63034.13	0
High Density Residential	46.57	<0.1	46.57	0
Rural Residential	15346.34	<0.1	15346.34	0
Pasture	32271067.87	99.7	12908427.15	60
Total	32360182.97	100.0	12991129.72	N/A

Table E.2b. Required annual reductions in direct nonpoint sources in subwatershed 2302 of the Sheep Creek watershed (Hydrologic Unit L23)

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent reduction
Cattle in stream	588,547	86.39	0	100.00
Wildlife in stream	74,899	10.99	14,980	80.00
Straight pipes	17,794	2.61	0	100.00
Total	681,240	100.00	14,980	97.80

Table E.3a.Required annual reductions in nonpoint sources in subwatershed 2303 of the Sheep Creek watershed (Hydrologic Unit L23)

Land use	Current conditions load (x 10^8 cfu)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu)	Percent reduction
Commercial/ Industrial	0.30	<0.1	0.30	0
Cropland	0.06	<0.1	0.02	60
Forest	471302.49	11.2	471302.49	0
High Density Residential	296.57	<0.1	296.57	0
Rural Residential	12765.58	0.3	12765.58	0
Pasture	3735455.29	88.5	1494182.12	60
Total	4219820.29	100.0	1974547.08	N/A

Table E.3b. Required annual reductions in direct nonpoint sources in subwatershed 2303 of the Sheep Creek watershed (Hydrologic Unit L23)

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent reduction
Cattle in stream	239,144	59.43	0	100.00
Wildlife in stream	127,649	31.72	25,530	80.00
Straight pipes	35,588	8.84	0	100.00
Total	402,380	100.00	25,530	93.66

Table E.4a.Required annual reductions in nonpoint sources in subwatershed 2304 of the Sheep Creek watershed (Hydrologic Unit L23)

Land use	Current conditions load (x 10^8 cfu)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu)	Percent reduction
Commercial/ Industrial	0.01	<0.1	0.01	0
Cropland	<0.01	<0.1	<0.01	60
Forest	41812.66	1.1	41812.66	0
High Density Residential	99.54	<0.1	99.54	0
Rural Residential	27751.74	0.7	27751.74	0
Pasture	3770072.29	98.2	1508028.92	60
Total	3838736.24	100.0	1577692.87	N/A

Table E.4b. Required annual reductions in direct nonpoint sources in subwatershed 2304 of the Sheep Creek watershed (Hydrologic Unit L23)

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent reduction
Cattle in stream	16,095	90.78	0	100.00
Wildlife in stream	151	0.85	30	80.00
Straight pipes	1,483	8.36	0	100.00
Total	17,729	100.00	30	99.83

Table E.5a.Required annual reductions in nonpoint sources in subwatershed 2305 of the Sheep Creek watershed (Hydrologic Unit L23)

Land use	Current conditions load (x 10^8 cfu)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu)	Percent reduction
Commercial/ Industrial	2.85	<0.1	2.85	0
Cropland	158.75	<0.1	63.50	60
Forest	16241.34	0.4	16241.34	0
High Density Residential	122.61	<0.1	122.61	0
Rural Residential	24231.45	0.6	24231.45	0
Pasture	4165528.43	99.0	1666211.37	60
Total	4206285.43	100.0	1706873.12	N/A

Table E.5b. Required annual reductions in direct nonpoint sources in subwatershed 2305 of the Sheep Creek watershed (Hydrologic Unit L23)

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent reduction
Cattle in stream	133,271	75.33	0	100.00
Wildlife in stream	43,646	24.67	8,729	80.00
Straight pipes	0	0.00	0	100.00
Total	176,917	100.00	8,729	95.07

Table E.6a. Required annual reductions in nonpoint sources in subwatershed 2306 of the Sheep Creek watershed (Hydrologic Unit L23)

Land use	Current conditions load (x 10^8 cfu)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu)	Percent reduction
Commercial/ Industrial	1.63	<0.1	1.63	0
Cropland	0.03	<0.1	0.01	60
Forest	63212.78	0.8	63212.78	0
High Density Residential	161.81	<0.1	161.81	0
Rural Residential	85545.74	1.0	85545.74	0
Pasture	8027388.76	98.2	3210955.50	60
Total	8176310.74	100.0	3359877.47	N/A

Table E.6b. Required annual reductions in direct nonpoint sources in subwatershed 2306 of the Sheep Creek watershed (Hydrologic Unit L23)

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent reduction
Cattle in stream	206,614	74.96	0	100.00
Wildlife in stream	69,029	25.04	13,806	80.00
Straight pipes	0	0.00	0	100.00
Total	275,643	100.00	13,806	94.99

Table E.7a.Required annual reductions in nonpoint sources in subwatershed 2501 of the Elk Creek watershed (Hydrologic Unit L25)

Land use	Current conditions load (x 10^8 cfu)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu)	Percent reduction
Commercial/ Industrial	<0.01	<0.1	<0.01	0
Cropland	<0.01	<0.1	<0.01	60
Forest	6298.15	0.7	6298.15	0
High Density Residential	0.45	<0.1	0.45	0
Rural Residential	2673.16	0.3	2673.16	0
Pasture	927782.36	99.0	371112.94	60
Total	936754.12	100.0	380084.70	N/A

Table E.7b. Required annual reductions in direct nonpoint sources in subwatershed 2501 of the Elk Creek watershed (Hydrologic Unit L25)

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent reduction
Cattle in stream	119,926	77.51	3,598	97.00
Wildlife in stream	34,800	22.49	10,440	70.00
Straight pipes	0	0.00	0	100.00
Total	154,726	100.00	14,038	90.93

Table E.8a.Required annual reductions in nonpoint sources in subwatershed 2502 of the Elk Creek watershed (Hydrologic Unit L25)

Land use	Current conditions load (x 10^8 cfu)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu)	Percent reduction
Commercial/ Industrial	<0.01	<0.1	<0.01	0
Cropland	<0.01	<0.1	<0.01	60
Forest	38761.34	7.0	38761.34	0
High Density Residential	0.03	<0.1	0.03	0
Rural Residential	85.52	<0.1	85.52	0
Pasture	517712.54	93.0	207085.02	60
Total	556556.43	100.0	245931.91	N/A

Table E.8b. Required annual reductions in direct nonpoint sources in subwatershed 2502 of the Elk Creek watershed (Hydrologic Unit L25)

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent reduction
Cattle in stream	145,035	69.09	4,351	97.00
Wildlife in stream	64,887	30.91	19,466	70.00
Straight pipes	0	0.00	0	100.00
Total	209,922	100.00	23,817	88.65

Table E.9a.Required annual reductions in nonpoint sources in subwatershed 2503 of the Elk Creek watershed (Hydrologic Unit L25)

Land use	Current conditions load (x 10^8 cfu)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu)	Percent reduction
Commercial/ Industrial	74.03	<0.1	74.03	0
Cropland	313.05	<0.1	125.22	60
Forest	76294.04	0.4	76294.04	0
High Density Residential	3720.38	<0.1	3720.38	0
Rural Residential	675915.41	3.8	675915.41	0
Pasture	17234718.46	95.8	6893887.38	60
Total	17991035.36	100.0	7650016.46	N/A

Table E.9b. Required annual reductions in direct nonpoint sources in subwatershed 2503 of the Elk Creek watershed (Hydrologic Unit L25)

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent reduction
Cattle in stream	368,038	66.96	11,041	97.00
Wildlife in stream	163,842	29.81	49,153	70.00
Straight pipes	17,794	3.24	0	100.00
Total	549,674	100.00	60,194	89.05

Table E.10a. Required annual reductions in nonpoint sources in subwatershed 2504 of the Elk Creek watershed (Hydrologic Unit L25)

Land use	Current conditions load (x 10^8 cfu)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu)	Percent reduction
Commercial/ Industrial	14.97	<0.1	14.97	0
Cropland	35.56	<0.1	14.22	60
Forest	15504.29	0.3	15504.29	0
High Density Residential	78.48	<0.1	78.48	0
Rural Residential	13066.43	0.3	13066.43	0
Pasture	4679494.24	99.4	1871797.70	60
Total	4708193.95	100.0	1900476.09	N/A

Table E.10b. Required annual reductions in direct nonpoint sources in subwatershed 2504 of the Elk Creek watershed (Hydrologic Unit L25)

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent reduction
Cattle in stream	239,741	81.90	7,192	97.00
Wildlife in stream	52,989	18.10	15,897	70.00
Straight pipes	0	0.00	0	100.00
Total	292,730	100.00	23,089	92.11

Table E.11a. Required annual reductions in nonpoint sources in subwatershed 2505 of the Elk Creek watershed (Hydrologic Unit L25)

Land use	Current conditions load (x 10^8 cfu)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu)	Percent reduction
Commercial/ Industrial	0.34	<0.1	0.34	0
Cropland	<0.01	<0.1	<0.01	60
Forest	3773.29	2.5	3773.29	0
High Density Residential	13.93	<0.1	13.93	0
Rural Residential	4554.73	3.0	4554.73	0
Pasture	143860.68	94.5	57544.27	60
Total	152202.96	100.0	65886.56	N/A

Table E.11b. Required annual reductions in direct nonpoint sources in subwatershed 2505 of the Elk Creek watershed (Hydrologic Unit L25)

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent reduction
Cattle in stream	49,493	69.08	1,485	97.00
Wildlife in stream	22,153	30.92	6,646	70.00
Straight pipes	0	0.00	0	100.00
Total	71,646	100.00	8,131	88.65

Table E.12a. Required annual reductions in nonpoint sources in subwatershed 2506 of the Elk Creek watershed (Hydrologic Unit L25)

Land use	Current conditions load (x 10^8 cfu)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu)	Percent reduction
Commercial/ Industrial	33.14	<0.1	33.14	0
Cropland	15.72	<0.1	6.29	60
Forest	61969.25	0.4	61969.25	0
High Density Residential	25.19	<0.1	25.19	0
Rural Residential	127384.70	0.9	127384.70	0
Pasture	13695516.64	98.6	5478206.66	60
Total	13884944.65	100.0	5667625.23	N/A

Table E.12b. Required annual reductions in direct nonpoint sources in subwatershed 2506 of the Elk Creek watershed (Hydrologic Unit L25)

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent reduction
Cattle in stream	432,386	80.58	12,972	97.00
Wildlife in stream	104,219	19.42	31,266	70.00
Straight pipes	0	0.00	0	100.00
Total	536,605	100.00	44,238	91.76

Table E.13a. Required annual reductions in nonpoint sources in subwatershed 2507 of the Elk Creek watershed (Hydrologic Unit L25)

Land use	Current conditions load (x 10^8 cfu)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu)	Percent reduction
Commercial/ Industrial	2.05	<0.1	2.05	0
Cropland	0.44	<0.1	0.18	60
Forest	4407.61	1.7	4407.61	0
High Density Residential	26.55	<0.1	26.55	0
Rural Residential	17759.95	6.8	17759.95	0
Pasture	238034.41	91.5	95213.76	60
Total	260231.02	100.0	117410.10	N/A

Table E.13b. Required annual reductions in direct nonpoint sources in subwatershed 2507 of the Elk Creek watershed (Hydrologic Unit L25)

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent reduction
Cattle in stream	38,072	56.52	1,142	97.00
Wildlife in stream	29,284	43.48	8,785	70.00
Straight pipes	0	0.00	0	100.00
Total	67,356	100.00	9,927	85.26

Table E.14a. Required annual reductions in nonpoint sources in subwatershed 2508 of the Elk Creek watershed (Hydrologic Unit L25)

Land use	Current conditions load (x 10^8 cfu)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu)	Percent reduction
Commercial/ Industrial	21.98	<0.1	21.98	0
Cropland	293.61	<0.1	117.44	60
Forest	72470.64	0.2	72470.64	0
High Density Residential	159.92	<0.1	159.92	0
Rural Residential	373292.80	0.9	373292.80	0
Pasture	38989053.17	98.9	1559581.27	60
Total	39435292.13	100.0	2005644.05	N/A

Table E.14b. Required annual reductions in direct nonpoint sources in subwatershed 2508 of the Elk Creek watershed (Hydrologic Unit L25)

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent reduction
Cattle in stream	836,462	85.71	25,094	97.00
Wildlife in stream	139,456	14.29	41,837	70.00
Straight pipes	0	0.00	0	100.00
Total	975,918	100.00	66,931	93.14

Table E.15a. Required annual reductions in nonpoint sources in subwatershed 26a01 of the Machine Creek watershed (Hydrologic Unit L26a)

Land use	Current conditions load (x 10^8 cfu)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu)	Percent reduction
Commercial/ Industrial	0.63	<0.1	0.63	0
Cropland	90.83	<0.1	36.33	60
Forest	3708.02	0.2	3708.02	0
High Density Residential	10141.46	0.4	10141.46	0
Rural Residential	160.83	<0.1	160.83	0
Pasture	2321311.88	99.4	928524.75	60
Total	2335413.46	100.0	942572.02	N/A

Table E.15b. Required annual reductions in direct nonpoint sources in subwatershed 26a01 of the Machine Creek watershed (Hydrologic Unit L26a)

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent reduction
Cattle in stream	168,150	82.08	0	100.00
Wildlife in stream	36,723	17.92	12,853	65.00
Straight pipes	0	0.00	0	0.00
Total	204,873	100.00	12,853	93.73

Table E.16a. Required annual reductions in nonpoint sources in subwatershed 26a02 of the Machine Creek watershed (Hydrologic Unit L26a)

Land use	Current conditions load (x 10^8 cfu)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu)	Percent reduction
Commercial/ Industrial	0.10	<0.1	0.10	0
Cropland	196.81	<0.1	78.72	60
Forest	8941.10	0.2	8941.10	0
High Density Residential	29.30	<0.1	29.30	0
Rural Residential	1874.93	<0.1	1874.93	0
Pasture	3948451.29	99.7	1579380.52	60
Total	3959493.53	100.0	1590304.67	N/A

Table E.16b. Required annual reductions in direct nonpoint sources in subwatershed 26a02 of the Machine Creek watershed (Hydrologic Unit L26a)

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent reduction
Cattle in stream	173,438	77.02	0	100.00
Wildlife in stream	51,746	22.98	18,111	65.00
Straight pipes	0	0.00	0	0.00
Total	225,184	100.00	18,111	91.96

Table E.17a. Required annual reductions in nonpoint sources in subwatershed 26a03 of the Machine Creek watershed (Hydrologic Unit L26a)

Land use	Current conditions load (x 10^8 cfu)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu)	Percent reduction
Commercial/ Industrial	1.76	<0.1	1.76	0
Cropland	7.97	<0.1	3.19	60
Forest	1667.19	0.1	1667.19	0
High Density Residential	6.96	<0.1	6.96	0
Rural Residential	<0.01	<0.1	<0.01	0
Pasture	1647073.09	99.9	658829.24	60
Total	1648756.98	100.0	660508.34	N/A

Table E.17b. Required annual reductions in direct nonpoint sources in subwatershed 26a03 of the Machine Creek watershed (Hydrologic Unit L26a)

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent reduction
Cattle in stream	218,187	87.17	0	100.00
Wildlife in stream	32,112	12.83	11,239	65.00
Straight pipes	0	0.00	0	0.00
Total	250,299	100.00	11,239	95.51

Table E.18a. Required annual reductions in nonpoint sources in subwatershed 26a04 of the Machine Creek watershed (Hydrologic Unit L26a)

Land use	Current conditions load (x 10^8 cfu)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu)	Percent reduction
Commercial/ Industrial	<0.01	<0.1	<0.01	0
Cropland	50.70	<0.1	20.28	60
Forest	5136.46	<0.1	5136.46	0
High Density Residential	47.01	<0.1	47.01	0
Rural Residential	<0.01	<0.1	<0.01	0
Pasture	7369294.82	99.9	2947717.93	60
Total	7374529.00	100.0	2952921.68	N/A

Table E.18b. Required annual reductions in direct nonpoint sources in subwatershed 26a04 of the Machine Creek watershed (Hydrologic Unit L26a)

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent reduction
Cattle in stream	401,173	88.67	0	100.00
Wildlife in stream	51,268	11.33	17,944	65.00
Straight pipes	0	0.00	0	0.00
Total	452,441	100.00	17,944	96.03

Table E.19a. Required annual reductions in nonpoint sources in subwatershed 26a05 of the Machine Creek watershed (Hydrologic Unit L26a)

Land use	Current conditions load (x 10^8 cfu)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu)	Percent reduction
Commercial/ Industrial	0.18	<0.1	0.18	0
Cropland	48.47	<0.1	19.39	60
Forest	4916.19	0.3	4916.19	0
High Density Residential	7.53	<0.1	7.53	0
Rural Residential	10.99	<0.1	10.99	0
Pasture	1828155.76	99.7	731262.30	60
Total	1833139.13	100.0	736216.58	N/A

Table E.19b. Required annual reductions in direct nonpoint sources in subwatershed 26a05 of the Machine Creek watershed (Hydrologic Unit L26a)

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent reduction
Cattle in stream	148,933	78.53	0	100.00
Wildlife in stream	40,717	21.47	14,251	65.00
Straight pipes	0	0.00	0	0.00
Total	189,650	100.00	14,251	92.49

Table E.20a. Required annual reductions in nonpoint sources in subwatershed 26a06 of the Machine Creek watershed (Hydrologic Unit L26a)

Land use	Current conditions load (x 10^8 cfu)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu)	Percent reduction
Commercial/ Industrial	<0.01	<0.1	<0.01	0
Cropland	118.24	<0.1	47.30	60
Forest	2163.07	0.3	2163.07	0
High Density Residential	16.31	<0.1	16.31	0
Rural Residential	99066.26	14.6	99066.26	0
Pasture	576009.99	85.0	230404.00	60
Total	677373.86	100.0	331696.94	N/A

Table E.20b. Required annual reductions in direct nonpoint sources in subwatershed 26a06 of the Machine Creek watershed (Hydrologic Unit L26a)

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent reduction
Cattle in stream	99,938	77.12	0	100.00
Wildlife in stream	29,658	22.88	10,380	65.00
Straight pipes	0	0.00	0	0.00
Total	129,596	100.00	10,380	91.99

Table E.21a. Required annual reductions in nonpoint sources in subwatershed 26a07 of the Machine Creek watershed (Hydrologic Unit L26a)

Land use	Current conditions load (x 10^8 cfu)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu)	Percent reduction
Commercial/ Industrial	<0.01	<0.1	<0.01	0
Cropland	278.56	0.3	111.42	60
Forest	1996.4	1.8	1996.4	0
High Density Residential	0.10	<0.1	0.10	0
Rural Residential	10602.89	9.7	10602.89	0
Pasture	96318.44	88.2	38527.38	60
Total	109196.39	100.0	51238.19	N/A

Table E.21b. Required annual reductions in direct nonpoint sources in subwatershed 26a07 of the Machine Creek watershed (Hydrologic Unit L26a)

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent reduction
Cattle in stream	27,412	52.44	0	100.00
Wildlife in stream	24,863	47.56	8,702	65.00
Straight pipes	0	0.00	0	0.00
Total	52,275	100.00	8,702	83.35

Table E.22a. Required annual reductions in nonpoint sources in subwatershed 26a08 of the Machine Creek watershed (Hydrologic Unit L26a)

Land use	Current conditions load (x 10^8 cfu)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu)	Percent reduction
Commercial/ Industrial	0.11	<0.1	0.11	0
Cropland	779.94	0.8	311.98	60
Forest	663.40	0.7	663.40	0
High Density Residential	4.23	<0.1	4.23	0
Rural Residential	3200.53	3.3	3200.53	0
Pasture	93414.52	95.2	37365.81	60
Total	98062.74	100.0	41546.06	N/A

Table E.22b. Required annual reductions in direct nonpoint sources in subwatershed 26a08 of the Machine Creek watershed (Hydrologic Unit L26a)

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent reduction
Cattle in stream	29,167	52.73	0	100.00
Wildlife in stream	26,149	47.27	9,152	65.00
Straight pipes	0	0.00	0	0.00
Total	55,316	100.00	9,152	83.45

Table E.23a. Required annual reductions in nonpoint sources in subwatershed 26b01 of the Little Otter River watershed (Hydrologic Unit L26b)

Land use	Current conditions load (x 10^8 cfu)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu)	Percent reduction
Commercial/ Industrial	9.83	<0.1	3.93	60
Cropland	377.52	<0.1	151.01	60
Forest	18174.13	0.1	18174.13	0
High Density Residential	12632.95	<0.1	5053.18	60
Rural Residential	607420.32	3.8	242968.13	60
Pasture	15528025.63	96.0	6211210.25	60
Total	16166640.38	100.0	6477560.63	N/A

Table E.23b. Required annual reductions in direct nonpoint sources in subwatershed 26b01 of the Little Otter River watershed (Hydrologic Unit L26b)

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent reduction
Cattle in stream	582,881	85.63	0	100.00
Wildlife in stream	80,052	11.76	24,016	70.00
Straight pipes	17,794	2.61	0	100.00
Total	680,727	100.00	24,016	96.47

Table E.24a. Required annual reductions in nonpoint sources in subwatershed 26b02 of the Little Otter River watershed (Hydrologic Unit L26b)

Land use	Current conditions load (x 10^8 cfu)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu)	Percent reduction
Commercial/ Industrial	38.53	<0.1	15.41	60
Cropland	10.07	<0.1	4.03	60
Forest	4485.40	0.3	4485.40	0
High Density Residential	361690.37	24.9	144676.15	60
Rural Residential	1194.75	<0.1	477.90	60
Pasture	1085087.93	74.7	434035.17	60
Total	1452507.05	100.0	583694.06	N/A

Table E.24b. Required annual reductions in direct nonpoint sources in subwatershed 26b02 of the Little Otter River watershed (Hydrologic Unit L26b)

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent reduction
Cattle in stream	111,759	69.86	0	100.00
Wildlife in stream	48,227	30.14	14,468	70.00
Straight pipes	0	0.00	0	100.00
Total	159,986	100.00	14,468	90.96

Table E.25a. Required annual reductions in nonpoint sources in subwatershed 26b03 of the Little Otter River watershed (Hydrologic Unit L26b)

Land use	Current conditions load (x 10^8 cfu)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu)	Percent reduction
Commercial/ Industrial	4.33	<0.1	1.73	60
Cropland	0.90	<0.1	0.36	60
Forest	28165.37	0.3	28165.37	0
High Density Residential	169504.03	1.7	67801.61	60
Rural Residential	0.29	<0.1	0.12	60
Pasture	10057309.81	98.1	4022923.92	60
Total	10254984.74	100.0	4118893.12	N/A

Table E.25b. Required annual reductions in direct nonpoint sources in subwatershed 26b03 of the Little Otter River watershed (Hydrologic Unit L26b)

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent reduction
Cattle in stream	209,975	69.76	0	100.00
Wildlife in stream	91,004	30.24	27,301	70.00
Straight pipes	0	0.00	0	100.00
Total	300,979	100.00	27,301	90.93

Table E.26a. Required annual reductions in nonpoint sources in subwatershed 26b04 of the Little Otter River watershed (Hydrologic Unit L26b)

Land use	Current conditions load (x 10^8 cfu)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu)	Percent reduction
Commercial/ Industrial	34.47	<0.1	13.79	60
Cropland	4.34	<0.1	1.73	60
Forest	6402.33	1.9	6402.33	0
High Density Residential	233206.44	68.4	93282.58	60
Rural Residential	2051.23	0.6	820.49	60
Pasture	99408.65	29.1	39763.46	60
Total	341107.46	100.0	140284.38	N/A

Table E.26b. Required annual reductions in direct nonpoint sources in subwatershed 26b04 of the Little Otter River watershed (Hydrologic Unit L26b)

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent reduction
Cattle in stream	39,499	50.36	0	100.00
Wildlife in stream	38,940	49.64	11,682	70.00
Straight pipes	0	0.00	0	100.00
Total	78,439	100.00	11,682	85.11

Table E.27a. Required annual reductions in nonpoint sources in subwatershed 26b05 of the Little Otter River watershed (Hydrologic Unit L26b)

Land use	Current conditions load (x 10^8 cfu)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu)	Percent reduction
Commercial/ Industrial	4.63	<0.1	1.85	60
Cropland	106.66	<0.1	42.66	60
Forest	3757.49	0.3	3757.49	0
High Density Residential	3935.00	0.4	1574.00	60
Rural Residential	8025.67	0.7	3210.27	60
Pasture	1065547.99	98.5	426219.20	60
Total	1081377.44	100.0	434805.47	N/A

Table E.27b. Required annual reductions in direct nonpoint sources in subwatershed 26b05 of the Little Otter River watershed (Hydrologic Unit L26b)

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent reduction
Cattle in stream	73,941	69.57	0	100.00
Wildlife in stream	32,345	30.43	9,704	70.00
Straight pipes	0	0.00	0	100.00
Total	106,286	100.00	9,704	90.87

Table E.28a. Required annual reductions in nonpoint sources in subwatershed 26b06 of the Little Otter River watershed (Hydrologic Unit L26b)

Land use	Current conditions load (x 10^8 cfu)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu)	Percent reduction
Commercial/ Industrial	4.67	<0.1	1.87	60
Cropland	<0.01	<0.1	<0.01	60
Forest	6555.01	0.6	6555.01	0
High Density Residential	90.41	<0.1	36.16	60
Rural Residential	459.42	<0.1	183.77	60
Pasture	1029260.02	99.3	411704.01	60
Total	1036369.53	100.0	418480.82	N/A

Table E.28b. Required annual reductions in direct nonpoint sources in subwatershed 26b06 of the Little Otter River watershed (Hydrologic Unit L26b)

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent reduction
Cattle in stream	65,455	66.04	0	100.00
Wildlife in stream	33,657	33.96	10,097	70.00
Straight pipes	0	0.00	0	100.00
Total	99,112	100.00	10,097	89.81

Table E.29a. Required annual reductions in nonpoint sources in subwatershed 26b07 of the Little Otter River watershed (Hydrologic Unit L26b)

Land use	Current conditions load (x 10^8 cfu)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu)	Percent reduction
Commercial/ Industrial	3.21	<0.1	1.28	60
Cropland	3.91	<0.1	1.56	60
Forest	3266.53	0.9	3266.53	0
High Density Residential	63.12	<0.1	25.25	60
Rural Residential	177.53	<0.1	71.01	60
Pasture	354788.79	99.0	141915.52	60
Total	358303.08	100.0	145281.15	N/A

Table E.29b. Required annual reductions in direct nonpoint sources in subwatershed 26b07 of the Little Otter River watershed (Hydrologic Unit L26b)

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent reduction
Cattle in stream	33,574	56.62	0	100.00
Wildlife in stream	25,727	43.38	7,718	70.00
Straight pipes	0	0.00	0	100.00
Total	59,301	100.00	7,718	86.98

Table E.30a. Required annual reductions in nonpoint sources in subwatershed 26b08 of the Little Otter River watershed (Hydrologic Unit L26b)

Land use	Current conditions load (x 10^8 cfu)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu)	Percent reduction
Commercial/ Industrial	0.05	<0.1	0.02	60
Cropland	549.05	<0.1	219.62	60
Forest	8453.58	0.4	8453.58	0
High Density Residential	3.24	<0.1	1.29	60
Rural Residential	30174.30	1.6	12069.72	60
Pasture	1846726.03	97.9	738690.41	60
Total	1885906.24	100.0	759434.64	N/A

Table E.30b. Required annual reductions in direct nonpoint sources in subwatershed 26b08 of the Little Otter River watershed (Hydrologic Unit L26b)

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent reduction
Cattle in stream	16,497	30.65	0	100.00
Wildlife in stream	37,328	69.35	11,198	70.00
Straight pipes	0	0.00	0	100.00
Total	53,825	100.00	11,198	79.20

Table E.31a. Required annual reductions in nonpoint sources in subwatershed 26b09 of the Little Otter River watershed (Hydrologic Unit L26b)

Land use	Current conditions load (x 10^8 cfu)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu)	Percent reduction
Commercial/ Industrial	<0.01	<0.1	<0.01	60
Cropland	1.20	<0.1	0.48	60
Forest	2092.06	0.6	2092.06	0
High Density Residential	0.14	<0.1	0.06	60
Rural Residential	35466.53	10.7	14186.61	60
Pasture	293870.23	88.7	117548.09	60
Total	331430.16	100.0	133827.30	N/A

Table E.31b. Required annual reductions in direct nonpoint sources in subwatershed 26b09 of the Little Otter River watershed (Hydrologic Unit L26b)

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent reduction
Cattle in stream	21,894	48.98	0	100.00
Wildlife in stream	22,809	51.02	6,843	70.00
Straight pipes	0	0.00	0	100.00
Total	44,703	100.00	6,843	84.69

Table E.32a. Required annual reductions in nonpoint sources in subwatershed 2801 of the Lower Big Otter River watershed (Hydrologic Unit L28)

Land use	Current conditions load (x 10^8 cfu)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu)	Percent reduction
Commercial/ Industrial	2.11	<0.1	2.11	0
Cropland	0.43	<0.1	0.21	50
Forest	111452.08	3.6	111452.08	0
High Density Residential	3.73	<0.1	3.73	0
Rural Residential	119413.83	3.9	119413.83	0
Pasture	2831520.24	92.5	1415760.12	50
Total	3062392.43	100.0	1646632.09	N/A

Table E.32b. Required annual reductions in direct nonpoint sources in subwatershed 2801 of the Lower Big Otter River watershed (Hydrologic Unit L28)

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent reduction
Cattle in stream	94,860	61.29	0	100.00
Wildlife in stream	59,917	38.71	29,959	50.00
Straight pipes	0	0.00	0	100.00
Total	154,777	100.00	29,959	80.64

Table E.33a. Required annual reductions in nonpoint sources in subwatershed 2802 of the Lower Big Otter River watershed (Hydrologic Unit L28)

Land use	Current conditions load (x 10^8 cfu)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu)	Percent reduction
Commercial/ Industrial	<0.01	<0.1	<0.01	0
Cropland	30.78	<0.1	15.39	50
Forest	1566.65	<0.1	1566.65	0
High Density Residential	0.01	<0.1	0.01	0
Rural Residential	<0.01	<0.1	<0.01	0
Pasture	2186029.86	99.9	1093014.93	50
Total	2187627.30	100.0	1094596.98	N/A

Table E.33b. Required annual reductions in direct nonpoint sources in subwatershed 2802 of the Lower Big Otter River watershed (Hydrologic Unit L28)

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent reduction
Cattle in stream	123,549	87.60	0	100.00
Wildlife in stream	17,494	12.40	8,747	50.00
Straight pipes	0	0.00	0	100.00
Total	141,043	100.00	8,747	93.80

Table E.34a. Required annual reductions in nonpoint sources in subwatershed 2803 of the Lower Big Otter River watershed (Hydrologic Unit L28)

Land use	Current conditions load (x 10^8 cfu)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu)	Percent reduction
Commercial/ Industrial	9.27	<0.1	9.27	0
Cropland	5.77	<0.1	2.89	50
Forest	39288.09	2.7	39288.09	0
High Density Residential	8.56	<0.1	8.56	0
Rural Residential	16694.09	1.2	16694.09	0
Pasture	1389585.41	96.1	694792.70	50
Total	1445591.19	100.0	750795.60	N/A

Table E.34b. Required annual reductions in direct nonpoint sources in subwatershed 2803 of the Lower Big Otter River watershed (Hydrologic Unit L28)

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent reduction
Cattle in stream	125,513	76.23	0	100.00
Wildlife in stream	39,129	23.77	19,565	50.00
Straight pipes	0	0.00	0	100.00
Total	164,642	100.00	19,565	88.12

Table E.35a. Required annual reductions in nonpoint sources in subwatershed 2804 of the Lower Big Otter River watershed (Hydrologic Unit L28)

Land use	Current conditions load (x 10^8 cfu)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu)	Percent reduction
Commercial/ Industrial	9.43	<0.1	9.43	0
Cropland	5.47	<0.1	2.74	50
Forest	3935.85	0.7	3935.85	0
High Density Residential	47.76	<0.1	47.76	0
Rural Residential	260.84	<0.1	260.84	0
Pasture	558411.52	99.2	279205.76	50
Total	562670.87	100.0	283462.38	N/A

Table E.35b. Required annual reductions in direct nonpoint sources in subwatershed 2804 of the Lower Big Otter River watershed (Hydrologic Unit L28)

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent reduction
Cattle in stream	77,200	81.90	0	100.00
Wildlife in stream	17,064	18.10	8,532	50.00
Straight pipes	0	0.00	0	100.00
Total	94,264	100.00	8,532	90.95

Table E.36a. Required annual reductions in nonpoint sources in subwatershed 2805 of the Lower Big Otter River watershed (Hydrologic Unit L28)

Land use	Current conditions load (x 10^8 cfu)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu)	Percent reduction
Commercial/ Industrial	6.10	<0.1	6.10	0
Cropland	268.99	<0.1	134.49	50
Forest	216987.68	3.6	216987.68	0
High Density Residential	4505.66	<0.1	4505.66	0
Rural Residential	1088782.05	17.9	1088782.05	0
Pasture	4768550.86	78.4	2384275.43	50
Total	6079101.34	100.0	3694691.41	N/A

Table E.36b. Required annual reductions in direct nonpoint sources in subwatershed 2805 of the Lower Big Otter River watershed (Hydrologic Unit L28)

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent reduction
Cattle in stream	233,154	67.48	0	100.00
Wildlife in stream	94,585	27.37	47,293	50.00
Straight pipes	17,794	5.15	0	100.00
Total	345,533	100.00	47,293	86.31

Table E.37a. Required annual reductions in nonpoint sources in subwatershed 2806 of the Lower Big Otter River watershed (Hydrologic Unit L28)

Land use	Current conditions load (x 10^8 cfu)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu)	Percent reduction
Commercial/ Industrial	50.07	<0.1	50.07	0
Cropland	478.79	<0.1	239.40	50
Forest	438102.18	6.3	438102.18	0
High Density Residential	892.75	<0.1	892.75	0
Rural Residential	100532.17	1.4	100532.17	0
Pasture	6420693.41	92.2	3210346.70	50
Total	6960749.38	100.0	3750163.27	N/A

Table E.37b. Required annual reductions in direct nonpoint sources in subwatershed 2806 of the Lower Big Otter River watershed (Hydrologic Unit L28)

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent reduction
Cattle in stream	150,924	55.92	0	100.00
Wildlife in stream	118,947	44.08	59,473	50.00
Straight pipes	0	0.00	0	100.00
Total	269,871	100.00	59,473	77.96

Table E.38a. Required annual reductions in nonpoint sources in subwatershed 2807 of the Lower Big Otter River watershed (Hydrologic Unit L28)

Land use	Current conditions load (x 10^8 cfu)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu)	Percent reduction
Commercial/ Industrial	<0.01	<0.1	<0.01	0
Cropland	366.93	<0.1	183.46	50
Forest	42531.47	5.9	42531.47	0
High Density Residential	2.27	<0.1	2.27	0
Rural Residential	94944.15	13.1	94944.15	0
Pasture	587980.77	81.0	293990.39	50
Total	725825.59	100.0	431651.74	N/A

Table E.38b. Required annual reductions in direct nonpoint sources in subwatershed 2807 of the Lower Big Otter River watershed (Hydrologic Unit L28)

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent reduction
Cattle in stream	44,718	54.93	0	100.00
Wildlife in stream	36,688	45.07	18,344	50.00
Straight pipes	0	0.00	0	100.00
Total	81,406	100.00	18,344	77.47

Table E.39a. Required annual reductions in nonpoint sources in subwatershed 2808 of the Lower Big Otter River watershed (Hydrologic Unit L28)

Land use	Current conditions load (x 10^8 cfu)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu)	Percent reduction
Commercial/ Industrial	5.48	<0.1	5.48	0
Cropland	581.07	<0.1	290.54	50
Forest	8712.30	0.7	8712.30	0
High Density Residential	1.57	<0.1	1.57	0
Rural Residential	2798.53	0.2	2798.53	0
Pasture	1239843.47	99.0	619921.74	50
Total	1251942.43	100.0	631730.16	N/A

Table E.39b. Required annual reductions in direct nonpoint sources in subwatershed 2808 of the Lower Big Otter River watershed (Hydrologic Unit L28)

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent reduction
Cattle in stream	110,678	81.70	0	100.00
Wildlife in stream	24,789	18.30	12,394	50.00
Straight pipes	0	0.00	0	100.00
Total	135,467	100.00	12,394	90.85

APPENDIX F.

Stream Flow Charts for TMDL Allocation Period

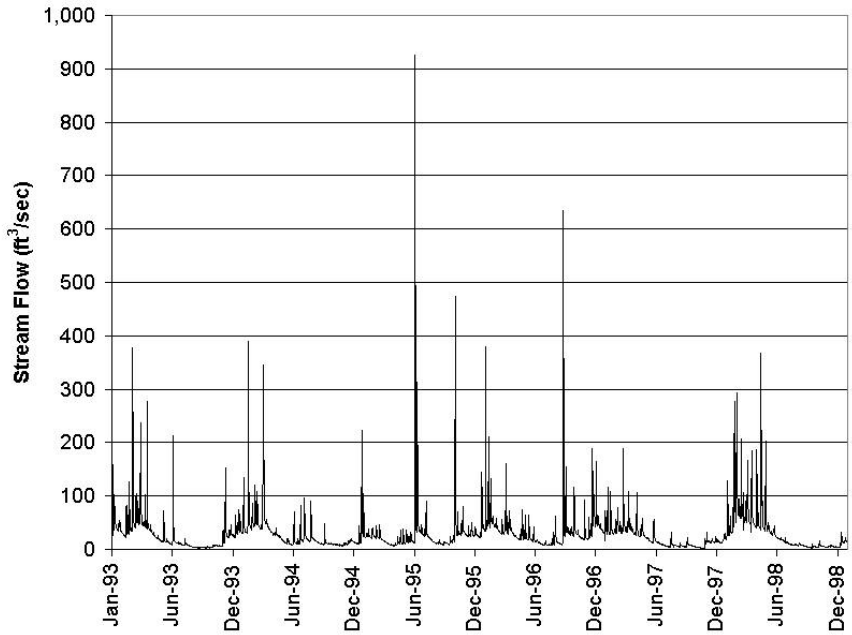


Figure F.1. Stream flow for Sheep Creek during TMDL allocation period (1/1/1993 through 12/31/1998).

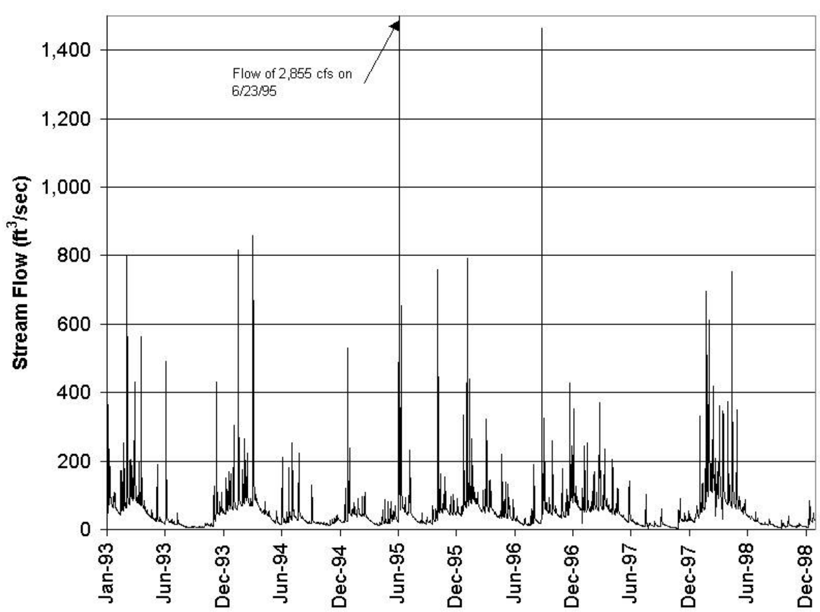
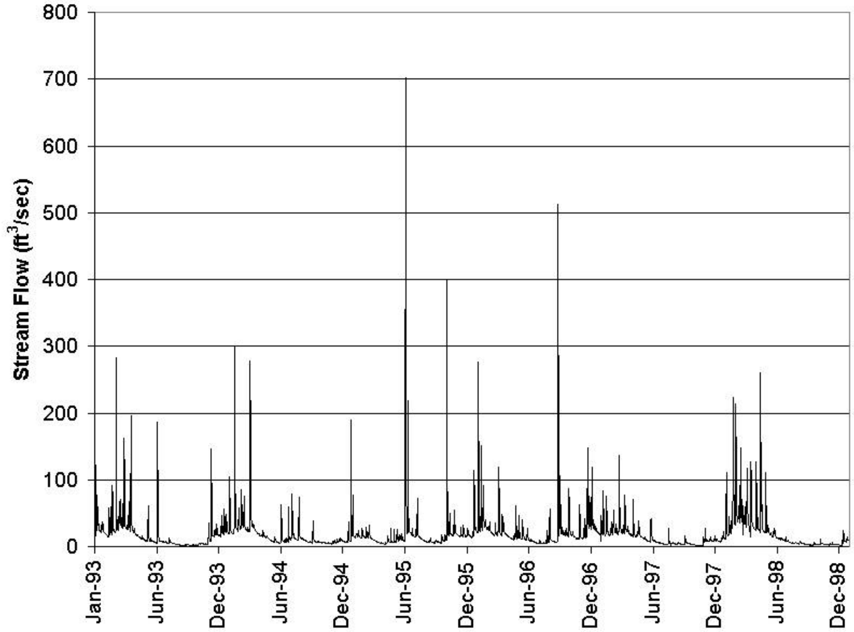


Figure F.2. Stream flow for Elk Creek during TMDL allocation period (1/1/1993 through 12/31/1998).



FigureF.3. Stream flow for Machine Creek during TMDL allocation period (1/1/1993 through 12/31/1998).

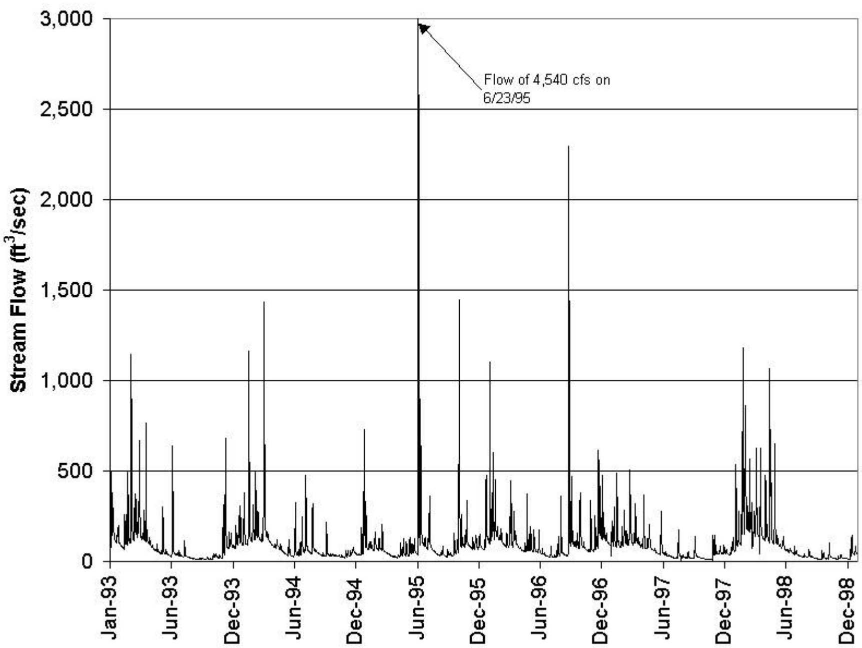


Figure F.4. Stream flow for the Little Otter River during TMDL allocation period (1/1/1993 through 12/31/1998).

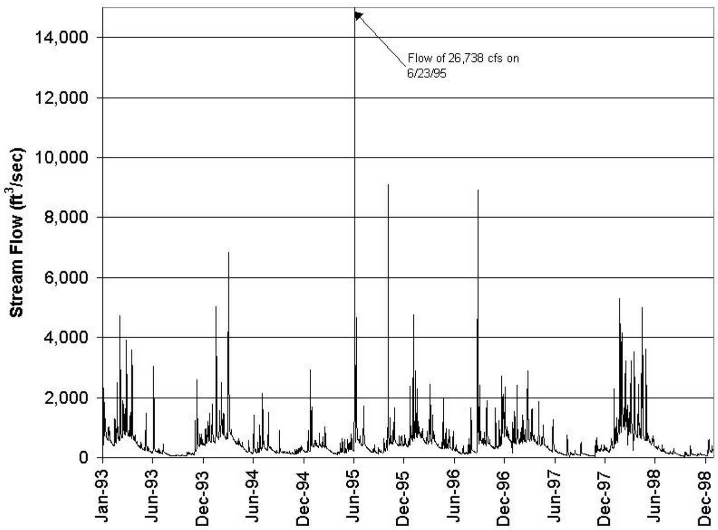


Figure F.5. Stream flow for the Lower Big Otter River during TMDL allocation period (1/1/1993 through 12/31/1998).

APPENDIX G.

Observed Fecal Coliform Concentrations and Antecedent Rainfall

Table G.1. Observed FC concentrations and antecedent rainfall for Sheep Creek

Station	Date	cfu/100ml	Total Rainfall for sampling day and preceding 5 days
4ASEE003.16	8/16/1993	6700	0
4ASEE003.16	11/3/1993	500	0.87
4ASEE003.16	2/9/1994	1400	0.59
4ASEE003.16	5/16/1994	4400	0.59
4ASEE003.16	8/9/1994	4600	0
4ASEE003.16	11/8/1994	300	0
4ASEE003.16	2/21/1995	8000	0.24
4ASEE003.16	5/15/1995	8000	0.91
4ASEE003.16	8/14/1995	8000	0
4ASEE003.16	11/14/1995	300	1.05
4ASEE003.16	2/12/1996	1900	0.4
4ASEE003.16	5/1/1996	200	0.96
4ASEE003.16	8/13/1996	8000	1.74
4ASEE003.16	11/12/1996	1100	1.92
4ASEE003.16	2/24/1997	100	0.38
4ASEE003.16	5/27/1997	3400	0.19
4ASEE003.16	8/13/1997	500	0.21
4ASEE003.16	11/18/1997	8000	0.25
4ASEE003.16	2/18/1998	100	1.64
4ASEE003.16	5/12/1998	500	1
4ASEE003.16	8/18/1998	400	0.36
4ASEE003.16	11/5/1998	1100	0.44

Table G.2. Observed FC concentrations and antecedent rainfall for Stony Creek

Station	Date	cfu/100ml	Total Rainfall for sampling day and preceding 5 days
4ASCB004.58	8/6/1991	100	0.35
4ASCB004.58	8/26/1996	100	0.07

Table G.3. Observed FC concentrations and antecedent rainfall for Elk Creek

Station	Date	cfu/100ml	Total Rainfall for sampling day and preceding 5 days
4AECR003.02	8/19/1992	300	0.08
4AECR003.02	9/21/1993	2000	0.78
4AECR003.02	12/7/1993	700	2.85
4AECR003.02	3/14/1994	200	0.79
4AECR003.02	6/22/1994	2500	0.00
4AECR003.02	9/13/1994	100	0.00
4AECR003.02	12/13/1994	300	0.55
4AECR003.02	3/22/1995	600	0.07
4AECR003.02	6/14/1995	4300	1.31
4AECR003.02	9/19/1995	800	0.98
4AECR003.02	12/6/1995	600	0.00
4AECR003.02	3/4/1996	300	0.05
4AECR003.02	6/4/1996	600	0.13
4AECR003.02	9/17/1996	8000	1.53
4AECR003.02	12/16/1996	200	1.11
4AECR003.02	3/26/1997	600	0.28
4AECR003.02	6/23/1997	1800	0.08
4AECR003.02	9/29/1997	8000	0.00
4AECR003.02	12/15/1997	100	0.29
4AECR003.02	3/30/1998	300	0.00
4AECR003.02	6/11/1998	700	0.44
4AECR003.02	9/16/1998	200	0.00
4AECR003.02	12/2/1998	300	0.00

Table G.4. Observed FC concentrations and antecedent rainfall for Machine Creek

Station	Date	cfu/100ml	Total Rainfall for sampling day and preceding 5 days
4AMCR004.60	8/20/1992	1500	0.08
4AMCR004.60	9/1/1993	1300	0.17
4AMCR004.60	12/1/1993	1900	2.09
4AMCR004.60	3/1/1994	300	0.71
4AMCR004.60	6/1/1994	1300	0
4AMCR004.60	9/7/1994	800	0.01
4AMCR004.60	12/5/1994	7900	0.56
4AMCR004.60	3/6/1995	100	0.2
4AMCR004.60	6/19/1995	1300	0.16
4AMCR004.60	9/5/1995	1700	0.97
4AMCR004.60	12/4/1995	300	0.25
4AMCR004.60	3/4/1996	100	0.05
4AMCR004.60	6/3/1996	2800	0.05

Table G.5. Observed FC concentrations and antecedent rainfall for Little Otter River

Station	Date	cfu/100ml	Total Rainfall for sampling day and preceding 5 days
4ALOR014.75	8/2/1988	100	0.00
4ALOR014.75	9/21/1988	2000	0.38
4ALOR014.75	10/13/1988	100	0.00
4ALOR014.75	11/3/1988	200	0.71
4ALOR014.75	1/23/1989	100	0.00
4ALOR014.75	3/27/1989	100	0.86
4ALOR014.75	4/24/1989	400	0.00
4ALOR014.75	5/22/1989	200	0.07
4ALOR014.75	5/25/1989	300	0.60
4ALOR014.75	6/27/1989	1200	0.44
4ALOR014.75	7/25/1989	400	0.00
4ALOR014.75	9/20/1989	1300	5.07
4ALOR014.75	11/15/1989	100	0.10
4ALOR014.75	12/20/1989	100	0.05
4ALOR014.75	1/24/1990	100	0.25
4ALOR014.75	2/27/1990	400	0.40
4ALOR014.75	3/27/1990	600	0.41
4ALOR014.75	5/24/1990	4200	0.99
4ALOR014.75	6/4/1990	1000	0.00
4ALOR014.75	6/14/1990	1300	2.07
4ALOR014.75	7/17/1990	800	2.52
4ALOR014.75	8/15/1990	400	0.04
4ALOR014.75	9/17/1990	300	1.63
4ALOR014.75	10/18/1990	900	1.80
4ALOR014.75	11/8/1990	200	0.10
4ALOR014.75	12/17/1990	300	0.53
4ALOR014.75	1/15/1991	3000	1.61
4ALOR014.75	3/25/1991	900	0.50
4ALOR014.75	3/26/1991	400	0.56
4ALOR014.75	4/29/1991	1200	0.69
4ALOR014.75	5/21/1991	1600	1.51
4ALOR014.75	6/11/1991	700	0.00
4ALOR014.75	9/12/1991	100	0.00
4ALOR014.75	10/7/1991	100	0.53
4ALOR014.75	12/12/1991	700	0.35
4ALOR014.75	1/9/1992	700	0.22

Table G.5. (continued) . Observed FC concentrations and antecedent rainfall for Little Otter River (station 4ALOR014.75)

Station	Date	cfu/100ml	Total Rainfall for sampling day and preceding 5 days
4ALOR014.75	1/13/1992	1000	0.18
4ALOR014.75	2/12/1992	100	0.01
4ALOR014.75	3/11/1992	8000	2.13
4ALOR014.75	4/14/1992	100	0.09
4ALOR014.75	5/13/1992	100	2.05
4ALOR014.75	6/9/1992	600	1.25
4ALOR014.75	7/13/1992	100	0.00
4ALOR014.75	8/12/1992	600	0.34
4ALOR014.75	9/14/1992	300	0.71
4ALOR014.75	10/14/1992	100	0.34
4ALOR014.75	11/5/1992	500	2.54
4ALOR014.75	12/9/1992	500	0.00
4ALOR014.75	2/23/1993	100	0.00
4ALOR014.75	3/11/1993	400	0.00
4ALOR014.75	4/12/1993	8000	0.89
4ALOR014.75	5/12/1993	900	0.28
4ALOR014.75	6/16/1993	900	0.57
4ALOR014.75	7/20/1993	1600	0.91
4ALOR014.75	8/16/1993	200	0.00
4ALOR014.75	9/21/1993	200	0.78
4ALOR014.75	10/20/1993	100	0.08
4ALOR014.75	11/3/1993	400	0.87
4ALOR014.75	12/7/1993	400	2.85
4ALOR014.75	1/11/1994	100	0.64
4ALOR014.75	2/9/1994	200	0.59
4ALOR014.75	3/14/1994	100	0.79
4ALOR014.75	4/12/1994	500	0.17
4ALOR014.75	5/16/1994	1900	0.59
4ALOR014.75	6/22/1994	1800	0.00
4ALOR014.75	7/12/1994	300	1.25
4ALOR014.75	8/9/1994	1100	0.00
4ALOR014.75	9/13/1994	600	0.00
4ALOR014.75	10/12/1994	300	0.25
4ALOR014.75	11/8/1994	300	0.00
4ALOR014.75	12/13/1994	200	0.55
4ALOR014.75	1/10/1995	900	0.99

Table G.5. (continued) . Observed FC concentrations and antecedent rainfall for Little Otter River (station 4ALOR014.75)

Station	Date	Cfu/100mL	Total Rainfall for sampling day and preceding 5 days
4ALOR014.75	2/21/1995	400	0.24
4ALOR014.75	3/22/1995	100	0.07
4ALOR014.75	4/13/1995	400	0.26
4ALOR014.75	5/15/1995	3300	0.91
4ALOR014.75	6/14/1995	1100	1.31
4ALOR014.75	7/27/1995	1800	1.55
4ALOR014.75	8/14/1995	400	0.00
4ALOR014.75	9/19/1995	200	0.98
4ALOR014.75	10/16/1995	100	1.02
4ALOR014.75	11/14/1995	300	1.05
4ALOR014.75	12/6/1995	400	0.00
4ALOR014.75	1/25/1996	4200	0.50
4ALOR014.75	2/12/1996	800	0.40
4ALOR014.75	3/4/1996	100	0.05
4ALOR014.75	4/3/1996	100	0.59
4ALOR014.75	5/1/1996	2400	0.96
4ALOR014.75	6/4/1996	2200	0.13
4ALOR014.75	7/17/1996	1000	1.65
4ALOR014.75	8/13/1996	8000	1.74
4ALOR014.75	9/17/1996	4800	1.53
4ALOR014.75	10/28/1996	2000	0.02
4ALOR014.75	11/12/1996	300	1.48
4ALOR014.75	12/16/1996	100	1.11
4ALOR014.75	1/15/1997	300	0.13
4ALOR014.75	2/24/1997	100	0.38
4ALOR014.75	3/26/1997	100	0.28
4ALOR014.75	4/21/1997	200	0.20
4ALOR014.75	5/27/1997	300	0.19
4ALOR014.75	6/23/1997	200	0.08
4ALOR014.75	7/21/1997	100	0.30
4ALOR014.75	8/13/1997	100	0.21
4ALOR014.75	1/6/1998	100	0.66
4ALOR014.75	1/26/1998	100	1.41

Table G.5. (continued) . Observed FC concentrations and antecedent rainfall for Little Otter River

Station	Date	cfu/100mL	Total Rainfall for sampling day and preceding 5 days
4ALOR014.75	2/10/1998	300	0.56
4ALOR014.75	2/18/1998	100	1.64
4ALOR014.75	3/4/1998	100	0.57
4ALOR014.75	3/30/1998	300	0.00
4ALOR014.75	4/20/1998	6500	2.74
4ALOR014.75	5/12/1998	1600	1.00
4ALOR014.75	6/11/1998	1600	0.44
4ALOR014.75	7/21/1998	100	0.24
4ALOR014.75	8/18/1998	400	0.36
4ALOR014.75	9/16/1998	1300	0.00
4ALOR014.75	10/19/1998	100	0.00
4ALOR014.75	11/5/1998	300	0.44
4ALOR014.75	12/2/1998	100	0.00

Table G.6. Observed FC concentrations and antecedent rainfall for Little Otter River (station 4AL0R014.33)

Station	Date	cfu/100ml	Total Rainfall for sampling day and preceding 5 days
4ALOR014.33	9/10/1988	300	0.40
4ALOR014.33	5/25/1989	400	0.60
4ALOR014.33	10/18/1989	120	1.71
4ALOR014.33	6/4/1990	100	0.00
4ALOR014.33	11/8/1990	400	0.10
4ALOR014.33	3/26/1991	100	0.56
4ALOR014.33	9/12/1991	1000	0.00
4ALOR014.33	10/7/1991	100	0.53
4ALOR014.33	12/12/1991	100	0.35
4ALOR014.33	1/9/1992	400	0.22
4ALOR014.33	1/13/1992	600	0.18
4ALOR014.33	2/12/1992	100	0.01
4ALOR014.33	3/11/1992	8000	2.13
4ALOR014.33	4/14/1992	100	0.09
4ALOR014.33	5/13/1992	600	2.05
4ALOR014.33	6/9/1992	800	1.25
4ALOR014.33	7/13/1992	1100	0.00
4ALOR014.33	8/12/1992	100	0.34
4ALOR014.33	9/14/1992	300	0.71
4ALOR014.33	10/14/1992	100	0.34
4ALOR014.33	11/5/1992	800	2.54
4ALOR014.33	12/9/1992	100	0.00
4ALOR014.33	2/23/1993	1400	1.39
4ALOR014.33	3/11/1993	300	0.00
4ALOR014.33	4/12/1993	4200	0.89
4ALOR014.33	5/12/1993	4100	0.28
4ALOR014.33	6/16/1993	600	0.57

Table G.7. Observed FC concentrations and antecedent rainfall for Little Otter River (station 4ALOR010.78)

Station	Date	cfu/100ml	Total Rainfall for sampling day and preceding 5 days
4ALOR010.78	8/19/1992	8000	0.08
4ALOR010.78	7/20/1993	3200	0.91
4ALOR010.78	8/16/1993	300	0.00
4ALOR010.78	9/21/1993	300	0.78
4ALOR010.78	10/20/1993	100	0.08
4ALOR010.78	11/3/1993	600	0.87
4ALOR010.78	12/7/1993	2800	2.85
4ALOR010.78	1/11/1994	300	0.64
4ALOR010.78	2/9/1994	800	0.59
4ALOR010.78	3/14/1994	100	0.79
4ALOR010.78	4/12/1994	400	0.17
4ALOR010.78	5/16/1994	2700	0.59
4ALOR010.78	6/22/1994	300	0.00
4ALOR010.78	7/12/1994	400	1.25
4ALOR010.78	8/9/1994	600	0.00
4ALOR010.78	9/13/1994	600	0.00
4ALOR010.78	10/12/1994	300	0.25
4ALOR010.78	11/8/1994	100	0.00
4ALOR010.78	12/13/1994	800	0.55
4ALOR010.78	1/10/1995	200	0.99
4ALOR010.78	2/21/1995	100	0.24
4ALOR010.78	3/22/1995	1000	0.07
4ALOR010.78	4/13/1995	500	0.26
4ALOR010.78	5/15/1995	400	0.91
4ALOR010.78	6/14/1995	1700	1.31
4ALOR010.78	7/27/1995	3600	1.55
4ALOR010.78	8/14/1995	300	0.00
4ALOR010.78	9/19/1995	100	0.98
4ALOR010.78	10/16/1995	700	1.02
4ALOR010.78	11/14/1995	1100	1.05
4ALOR010.78	12/6/1995	100	0.00
4ALOR010.78	1/25/1996	1800	0.50
4ALOR010.78	2/12/1996	1000	0.40
4ALOR010.78	3/4/1996	100	0.05
4ALOR010.78	4/3/1996	100	0.59
4ALOR010.78	5/1/1996	1200	0.96
4ALOR010.78	6/4/1996	3300	0.13

Table G.8 Observed FC concentrations and antecedent rainfall for Little Otter River (station 4ALOR008.64)

Station	Date	cfu/100ml	Total Rainfall for sampling day and preceding 5 days
4ALOR008.64	7/17/1996	600	1.65
4ALOR008.64	8/13/1996	8000	1.74
4ALOR008.64	9/17/1996	3400	1.53
4ALOR008.64	10/28/1996	300	0.02
4ALOR008.64	11/12/1996	100	1.48
4ALOR008.64	12/16/1996	200	1.11
4ALOR008.64	1/15/1997	100	0.13
4ALOR008.64	2/24/1997	200	0.38
4ALOR008.64	3/26/1997	100	0.28
4ALOR008.64	4/21/1997	300	0.20
4ALOR008.64	5/27/1997	100	0.19
4ALOR008.64	6/23/1997	1300	0.08
4ALOR008.64	7/21/1997	600	0.30
4ALOR008.64	8/13/1997	2400	0.21
4ALOR008.64	9/29/1997	4400	0.00
4ALOR008.64	10/21/1997	100	0.00
4ALOR008.64	11/18/1997	600	0.25
4ALOR008.64	12/15/1997	100	0.29
4ALOR008.64	1/26/1998	100	1.41
4ALOR008.64	2/18/1998	100	1.64
4ALOR008.64	3/30/1998	100	0.00
4ALOR008.64	4/20/1998	8000	2.74
4ALOR008.64	5/12/1998	3900	1.00
4ALOR008.64	6/11/1998	1200	0.44
4ALOR008.64	7/21/1998	400	0.24
4ALOR008.64	8/18/1998	800	0.36
4ALOR008.64	9/16/1998	300	0.00
4ALOR008.64	10/19/1998	200	0.00
4ALOR008.64	11/5/1998	100	0.44
4ALOR008.64	12/2/1998	100	0.00

Table G.9 Observed FC concentrations and antecedent rainfall for Lower Big Otter River (station 4ABOR000.62)			
Station	**Date**	**cfu/100ml**	**Total Rainfall for sampling day and preceding 5 days**
4ABOR000.62	9/12/1988	100	0.40
4ABOR000.62	12/5/1988	200	0.00
4ABOR000.62	3/7/1989	8000	1.51
4ABOR000.62	7/12/1989	800	0.29
4ABOR000.62	9/11/1989	100	0.86
4ABOR000.62	12/14/1989	100	0.79
4ABOR000.62	3/15/1990	600	0.12
4ABOR000.62	6/11/1990	8000	2.07
4ABOR000.62	9/18/1990	300	0.09
4ABOR000.62	12/10/1990	600	0.03
4ABOR000.62	3/11/1991	100	0.13
4ABOR000.62	9/12/1991	100	0.00
4ABOR000.62	12/12/1991	400	0.35
4ABOR000.62	3/11/1992	6600	2.13
4ABOR000.62	6/9/1992	1500	1.25
4ABOR000.62	9/14/1992	300	0.71
4ABOR000.62	12/9/1992	200	0.00
4ABOR000.62	2/23/1993	1700	1.39
4ABOR000.62	3/11/1993	100	0.00
4ABOR000.62	4/12/1993	500	0.89
4ABOR000.62	5/12/1993	8000	0.22
4ABOR000.62	6/16/1993	1000	0.57
4ABOR000.62	7/20/1993	1000	0.91
4ABOR000.62	8/16/1993	200	0.00
4ABOR000.62	9/21/1993	300	0.78
4ABOR000.62	10/20/1993	100	0.08
4ABOR000.62	11/3/1993	200	0.87
4ABOR000.62	12/7/1993	200	2.85
4ABOR000.62	1/11/1994	100	0.64
4ABOR000.62	2/9/1994	100	0.59
4ABOR000.62	3/14/1994	100	0.79
4ABOR000.62	6/22/1994	200	0.00
4ABOR000.62	7/12/1994	600	1.25
4ABOR000.62	8/9/1994	200	0.00
4ABOR000.62	9/13/1994	100	0.00
4ABOR000.62	10/12/1994	100	0.25
4ABOR000.62	11/8/1994	100	0.00

Table G.9. (continued) Observed FC concentrations and antecedent rainfall for Lower Big Otter River (station 4ABOR000.62)

Station	Date	cfu/100ml	Total Rainfall for sampling day and preceding 5 days
4ABOR000.62	12/13/1994	400	0.55
4ABOR000.62	1/10/1995	100	0.99
4ABOR000.62	2/21/1995	300	0.24
4ABOR000.62	3/22/1995	100	0.07
4ABOR000.62	4/13/1995	1100	0.26
4ABOR000.62	5/15/1995	800	0.91
4ABOR000.62	7/27/1995	2500	1.55
4ABOR000.62	8/14/1995	100	0.00
4ABOR000.62	9/19/1995	100	0.98
4ABOR000.62	10/16/1995	3800	1.02
4ABOR000.62	11/14/1995	1200	1.05
4ABOR000.62	12/6/1995	100	0.00
4ABOR000.62	1/25/1996	3500	0.50
4ABOR000.62	2/12/1996	100	0.40
4ABOR000.62	3/4/1996	100	0.05
4ABOR000.62	4/3/1996	100	0.59
4ABOR000.62	5/1/1996	4100	0.96
4ABOR000.62	6/4/1996	100	0.13
4ABOR000.62	7/17/1996	1600	1.65
4ABOR000.62	8/13/1996	8000	1.74
4ABOR000.62	9/17/1996	600	1.53
4ABOR000.62	10/28/1996	100	0.02
4ABOR000.62	11/12/1996	700	1.48
4ABOR000.62	12/16/1996	300	1.11
4ABOR000.62	1/15/1997	100	0.13
4ABOR000.62	2/24/1997	100	0.38
4ABOR000.62	3/26/1997	1100	0.28
4ABOR000.62	4/21/1997	100	0.20
4ABOR000.62	5/27/1997	100	0.19
4ABOR000.62	6/23/1997	100	0.08
4ABOR000.62	7/21/1997	100	0.30
4ABOR000.62	8/13/1997	100	0.21
4ABOR000.62	9/29/1997	800	0.00
4ABOR000.62	10/21/1997	100	0.00

Table G.9. (continued) Observed FC concentrations and antecedent rainfall for Lower Big Otter River (station 4ABOR000.62)

Station	Date	cfu/100ml	Total Rainfall for sampling day and preceding 5 days
4ABOR000.62	11/18/1997	100	0.25
4ABOR000.62	12/15/1997	100	0.29
4ABOR000.62	1/26/1998	100	1.41
4ABOR000.62	2/18/1998	1800	1.64
4ABOR000.62	3/30/1998	300	0.00
4ABOR000.62	4/20/1998	8000	2.74
4ABOR000.62	5/12/1998	3000	1.00
4ABOR000.62	6/11/1998	1900	0.44
4ABOR000.62	7/21/1998	100	0.24
4ABOR000.62	8/18/1998	300	0.36
4ABOR000.62	9/16/1998	100	0.00
4ABOR000.62	10/19/1998	200	0.00
4ABOR000.62	11/5/1998	100	0.44
4ABOR000.62	12/2/1998	100	0.00

APPENDIX H.

Comments and Responses

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION III
1650 Arch Street
Philadelphia, Pennsylvania 19103-2029

Mr. William Keeling
Virginia Department of Conservation and Recreation
203 Governor Street, Suite 213
Richmond, VA 23219-2094

Dear Mr. Keeling:

EPA has reviewed the draft Fecal Coliform TMDLs for Sheep Creek, Elk Creek, Machine Creek, Little Otter River, and Big Otter River. EPA appreciates the opportunity to review these draft documents and would like to request a copy of the models as well. Overall, these drafts are very good. They are easy to comprehend and follow. EPA was pleased to see that the Commonwealth included tables which documented the input parameter values used in HSPF. The TMDL equation and land use tables incorporated into each section of the report assisted in the review process as well. EPA has prepared the following comments on these draft TMDLs:

Section #1, Executive Summary.

The draft TMDL states that "Animal operations in the Sheep Creek watershed include beef, two dairies and horses." Could this be changed to state that "Animal operations in the Sheep Creek watershed included (#) beef cattle operations, (#) dairy operations, and (#) horse farms."? Similar writing can be found in the description of each watershed.

The draft TMDL states that "In the Sheep Creek watershed there were eight incidences of direct discharge of household wastewater (straight pipes) to the stream, and 182 failing septic systems." Can this statement be revised to state that "Based on modeling assumptions and best professional judgement it was projected that in the Sheep Creek watershed ..."? Similar writing can be found in the description of each watershed.

In the Machine Creek summary it states "There is one permitted point source of fecal coliform in Machine Creek watershed, but it is not discharging fecal coliform due to chlorination requirements." Was this point source modeled as though it was discharging fecal coliform at its permitted concentration, or is it modeled as though no fecal coliform is being discharged? There may still be some low level fecal coliform concentrations, even with chlorination. Data should be provided to document a fecal coliform concentration of zero.

The TMDLs for the Big Otter Watershed, like several other TMDLs developed in Virginia, call for large reductions in wildlife. Based on conversations with the Commonwealth, it is clear that the State has no intention to reduce wildlife populations in this watershed. The reductions in wildlife appear to be caused by a combination of the State's standards, the stream's designated use, and the Commonwealth's modeling approach. A strategy needs to be developed between the Commonwealth and EPA on how to address the wildlife issue for all of these watersheds.

Traditionally, EPA views a reduction of 50% or less in nonpoint source loading as feasible. Several of the waters in the Big Otter Watershed call for a greater than 50% reduction in their nonpoint source loading. Does the Commonwealth believe that these reductions are feasible, is there a reasonable assurance that these reductions can occur?

Was the Bacterial Indicator Tool used to determine the fecal coliform build-up/washoff parameters for HSPF?

Please add a table that documents the violation rate for all of the streams when all sources other than wildlife are removed. This information is needed in the justification of a phased allocation plan.

Could a table be added documenting the simulated versus observed fecal coliform concentration for sampling data on each of the subwatersheds?

Section #2, Introduction.

Section 2.5.2, Please define what is meant by a low potential for groundwater pollution movement. Is this due to the low permeability of the soils, the depth of the water table, the properties of the soil, or another factor?

Section 2.6.2.1, How were the New Jersey biosolids considered for future conditions?

Section 2.6.2.2, Is there any information on the amount of pet waste which is removed by the owners? This would lower the amount of pet waste available for runoff.

Section 2.6.2.3, Based on the report, it appears as though the reduction in dairy cows has already been incorporated into the allocation plans.

Section 2.6.2.3, Table 2.8, Do dairy cows spend the same amount of time in the streams as beef cattle do, even though they are confined for a portion of the day?

Section 2.6.3, If wildlife is considered as a loading to the commercial/industrial land use, it should be considered for the rural and high density residential land uses, as well.

Section #3, Modeling Process for TMDL Development.

Section 3.4.1, It seems as though for the existing conditions, the fecal coliform concentration from point sources is being zeroed out, and their permitted discharge concentration is being used for the allocation. However, later in the report it seems as though the allocation is being zeroed out too.

Section 3.4.3, How was the storage time determined? Was it assumed that all wastes were stored for the maximum holding time or was it split into a percent being stored for the maximum storage, a percent for the maximum storage minus one day, and a percent for maximum minus two days, etc.?

Section 3.4.3, Bullets three and four should both have wildlife loadings, as well.

Section 3.5.1, On page 55, the report states that "The overall quality of the regression between the flows at the two stations for the entire was good." Please elaborate on the word "entire".

Section 3.5.1, On page 60, the report documents the breakdown of the flow components. Is this for both pervious and impervious land segments? Was the hydrograph checked as well? Was the simulated baseflow 65 or 66%?

Section 3.5.1, Can a figure documenting the simulated vs observed flow results from January of 1996 through September of 1997 be provided?

Section 3.5.1, Can figures documenting the simulated flow for the other watersheds be provided as well?. Although there is no data to calibrate this data to, it would be helpful to visualize for which flow conditions the model is predicting elevated fecal coliform concentrations.

Section 4.0, TMDL for Sheep Creek Watershed

Section 4.1.4.1, Figure 4.2, Was the maximum concentration cap of the sampling method used in the 1970s 6,000 cfu/100 mL?

Section 4.2.2.1, It was assumed that the fecal coliform contribution to the rural residential land use was cfu/day. Is there any removal of fecal coliform as the septic wastes migrates up through the soil profile?

Section 4.3.2, The report states that the single permitted point source in the watershed was not considered significant because of the small flow rate. Was this discharge point considered in the allocation plan, because the waste load allocation is 0?

Section 4.3.4, Table 4.13, Kindly document the constituent concentration for the AOQC and IOQC in cfu / 100 mL as well.

Section 5.0, TMDL for Elk Creek Watershed

Section 5.1.4.1, Figure 5.2, Is it possible to include the dates and fecal coliform concentrations of these sampling events in an appendix (for all watersheds)? Is it possible to determine the weather conditions when these samples were taken to get a rough idea of the flow regime?

Section 5.1.4.2, Does the simulated data accurately reflect the stream surface data from the March 2000 sampling?

Section 5.2.2.1, Please reference the earlier discussion on how the Commonwealth determined the amount of septic systems and straight pipes. This comment can be applied to all of the TMDLs.

Section 5.2.2.3, In determining the amount of manure deposited by livestock to a stream, did the Commonwealth multiply the total livestock population by the average access to the stream or did they multiply the livestock for each subwatershed by the subwatershed's stream access?

Section 5.3.4, Figure 5.3, One of the goals was to insure that the simulated data had a higher fecal coliform concentration than the observed data, when the sample concentration maxed out at 8,000 cfu /100 mL. Yet, in figure 5.3 four of the five simulated data points are less than or equal to the observed data when the observed data has hit its maximum concentration cap. Please explain why the Commonwealth is comfortable with this calibration.

Section 5.3.4, The report mentions that the wash-off factor was changed to 2.4 inches per hour, however, Table 5.14 shows a wash-off factor of 1.8 inches.

Section 5.4.2, Seventy-five percent of the samples did not exceed the instantaneous standard of 1,000 cfu/100 mL. Several of the samples (based on figure 5.2) appear to show concentrations of fecal coliform below 200 cfu/100 mL. However, the model shows the geometric mean standard as being violated close to 100% of the time. Is the Commonwealth comfortable with this simulation, please elaborate?

Section #6, TMDL for Machine Creek Watershed

Section 6.1.4.1, It should be mentioned that monitoring site 4AMCR004.60 is downstream of where Skinnels and Nininger Creek confluence with Machine Creek.

Section 6.2.1, The draft TMDL states "The sole permitted point source in the Machine Creek watershed is the Body Camp Elementary School (VPDES Permit No. VA0020818) located on the southwestern boundary of the watershed (figure 2.3). The school is required to chlorinate and permitted to discharge fecal coliform at a rate of 200 cfu/100 mL." In the model was this facility treated as having a fecal coliform concentration of zero in the effluent?

Section 6.2.3, The draft TMDL states "However, other factors such as precipitation and proximity to streams also impact the amount of fecal coliform from upland areas that reaches the stream." Die-off should also be mentioned.

Section 6.3.4, The report states that there are 12 quarterly samples for Machine Creek, however, there appear to be 13 samples in Figure 6.2.

Section 6.3.4, Kindly verify the wash-off factor for Elk Creek.

Section 6.3.4, Figure 6.3, One of the calibration goals was to insure that "the simulated concentrations equaled or exceeded the capped concentrations of the observed values." There is a gross disparity between the simulated concentration and the sole observed capped concentration value. Please elaborate on this calibration.

Section 6.4.3, The report states that "Since a 100% reduction in direct deposition from cattle and a 60% reduction in direct deposits (scenario 5) did not achieve the TMDL goal, reductions were required from other sources." This statement makes it seem as though the Commonwealth first determines if reductions in cattle in-stream and wildlife will allow the water to attain standards and that only if these reductions do not work are alternatives investigated. Obviously, this is not the case, could this statement be reworded?

Section 8.4.3, Please elaborate on how unimpaired waters may be contributing to violations in the Big Otter River. Please illustrate that these waters were considered unimpaired based on the 1,000 cfu/ 100 mL standard and may in fact be violating the geometric mean of 200 cfu/100 mL.

Please feel free to contact me at 215-814-5236 if you have any questions or comments.

Sincerely,

Peter Gold
USEPA Region III

cc: Charles Martin, DEQ
Thomas Henry, EPA
Mark Bennett, DCR

October 26, 2000

Mr. Peter Gold
United States Environmental Protection Agency
Region III
1650 Arch Street
Philadelphia, Pennsylvania 19103-2029

Dear Mr. Gold:

The Virginia Department of Conservation and Recreation (VA DCR) appreciates EPA's comments on the draft document for the Fecal Coliform TMDLs for Sheep Creek, Elk Creek, Machine Creek, Little Otter River, and the Lower Big Otter River. VA DCR and its contractor have prepared responses to EPA's comments on these TMDLs. In this response EPA's comments have been restated in italics and then followed the comment(s) with the response for the particular comment(s).

The TMDLs for the Big Otter Watershed, like several other TMDLs developed in Virginia, call for large reductions in wildlife direct deposition to the streams. It is clear that the Commonwealth has no intention to reduce wildlife populations in these watersheds. The reductions in wildlife appear to be caused by a combination of the State's water quality fecal coliform standards, the stream's designated use, and the Commonwealth's modeling approach. A strategy needs to be developed between the Commonwealth and EPA on how to address the wildlife issue for all of these watersheds.

Chapter 1: Executive Summary

EPA: *The draft TMDL states that "Animal operations in the Sheep Creek watershed include beef, two dairies, and horses." Could this be changed to state that "Animal operations in the Sheep Creek watershed included (#) beef cattle operations, (#) dairy operations, and (#) horse farms."? Similar writing can be found in the description of each watershed.*

Response: Although data are available regarding the number of dairy *operations* in the watersheds, there are no data documenting the specific number of beef operations or horse farms. However, the text could be changed to read: "Animal operations in the Sheep Creek watershed include beef, two dairies, and horses. Although the total number of animals is available, the specific numbers of beef operations and horse farms are unknown." This change could be made for each watershed description.

EPA: *The draft TMDL states that "In the Sheep Creek watershed there were eight incidences of direct discharge of household wastewater (straight pipes) to the stream, and 182 failing septic systems." Can this statement be revised to state that "Based on modeling assumptions and best professional judgment it was projected that in the Sheep Creek watershed…"? Similar writing can be found in the description of each watershed.*

Response: The draft TMDL will be rephrased to read: "Based on modeling assumptions and best professional judgment, it was projected that in the Sheep Creek watershed there were eight incidences of direct discharge of household wastewater (straight pipes) to the stream, and 182 failing septic systems. This change can be made in the description for each watershed.

EPA: *In the Machine Creek summary it states "There is one permitted point source of fecal coliform in Machine Creek watershed, but it is not discharging fecal coliform due to chlorination requirements." Was this point source modeled as though it was discharging fecal coliform at its permitted concentration, or is it modeled as though no fecal coliform is being discharged? There may still be some low level fecal coliform concentrations, even with chlorination. Data should be provided to document a fecal coliform concentration of zero.*

Response: The simulation process as it pertains to permitted dischargers was based on instructions from VA DEQ to the TMDL contractor and undertaken in the following manner. For the existing condition runs, the permitted point source dischargers were assumed to not discharge FC due to chlorination. For the allocation runs, the permitted dischargers contributed a load that corresponded to a 200 cfu/ 100mL concentration in their permitted flow rate.

EPA: *Traditionally, EPA views a reduction of 50% or less in nonpoint source loading as feasible. Several of the waters in the Big Otter Watershed call for a greater than 50% reduction in their nonpoint source loading. Does the Commonwealth believe that these* *reductions are feasible, is there a reasonable assurance that these reductions can occur?*

Response: We believe that with intensive manure management and the reestablishment of functioning riparian buffer zones along all first order streams and significant ephemeral drainage ways these reductions can be achieved.

EPA: *Was the Bacterial Indicator Tool used to determine the fecal coliform build-up/washoff parameters for HSPF?*

Response: No. Our best professional judgment was used to determine the build-up/wash off factor for the FC load on the land surface.

EPA: *Please add a table that documents the violation rate for all of the streams when all sources other than wildlife are removed. This information is needed in the justification of a phased allocation plan.*

Response: Table 1 lists the violation rates for each of the watersheds when direct deposit from wildlife is the only source of FC in the watershed.

Table 1. Violation rates for watersheds when direct deposit from wildlife is the only source of FC.

Watershed	Violation Rate for 1,000 cfu/ml Instantaneous standard	Violation Rate for 200 cfu/ml Geometric Mean standard
Sheep Creek	0%	24.6%
Elk Creek	0%	10.6%
Machine Creek	0%	11.2%
Little Otter River	0%	0%
Big Otter River	0%	0%

EPA: Could a table be added documenting the simulated versus observed fecal coliform concentration for sampling data on each of the subwatersheds?

Response: A table that reports the observed and simulated values for side-by-side comparison could be misleading. The simulated values are reported on an average-daily basis while the observed values are instantaneous samples. The daily variation in FC levels that would be evident in the observed values should result in differences with the daily-average value for the simulated concentrations. These differences would not necessarily be due to modeling uncertainties. We believe the sparse observed data is better used to make general comparisons concerning the overall trends and seasonal fluctuations, rather than trying to compare the accuracy of two values (daily-average simulated and instantaneous observed values) that are not reporting the same information.

Chapter 2: Introduction

EPA: Section 2.5.2, Please define what is meant by a low potential for groundwater pollution movement. Is this due to the low permeability of the soils, the depth of the water table, the properties of the soil, or another factor?

Response: It means that the soils and geology in this area do not promote the movement of pollutants, such as fecal coliform, through the upper soil horizons to groundwater and then within the aquifer itself. Soils are generally deep with adequate fines and clay to prevent percolation of bacteria. Seasonally high water tables are also generally deeper than 6 feet. Aquifers in the area are of igneous origin and are not nearly as fractured and porous as sedimentary and limestone aquifers, which are more prone to transport of bacteria.

EPA: Section 2.6.2.1. How were the New Jersey biosolids considered for future conditions?

Response: They were not included in the allocations. This implies that any additional loadings due to additional biosolids applications would need to be off-set by reductions in allocated loadings.

EPA: Section 2.6.2.2, Is there any information on the amount of pet waste which is removed by the owners? This would lower the amount of pet waste available for runoff.

Response: There was not sufficient information available to represent the management of waste by pet owners. Therefore, we assumed that all pet waste was left on the land surface.

EPA: Section 2.6.2.3, Based on the report, it appears as though the reduction in dairy cows has already been incorporated into the allocation plans.

Response: The reductions in dairy cattle numbers have been incorporated into the allocation plans but the earlier dairy cattle numbers were used in the existing condition simulations.

EPA: Section 2.6.2.3, Table 2.8, Do dairy cows spend the same amount of time in the streams as beef cattle do, even though they are confined for a portion of the day?

Response: The amount of time that cattle spent in streams was a function of the amount of time that they had access to streams. If the cattle were confined for a portion of the day (dairy usually were, beef generally were not) then this reduced their access to the stream and we accounted for this. For beef and dairy in each subwatershed, we determined the equivalent numbers of cattle that had full time access to the streams and then used our seasonal hours/day in stream values (same for beef and dairy) to estimate direct manure/fecal coliform loadings to streams. The equivalent numbers of cattle with full access to steams was seasonal and was a function of the animal confinement schedules. Dairy cattle had much less access to streams than beef. We also considered the fact that dairy cattle produce higher manure/fecal coliform production rates than beef.

EPA: Section 2.6.3, If wildlife is considered as a loading to the commercial/industrial land use, it should be considered for the rural and high density residential land uses, as well.

Response: The commercial/industrial land use is assigned a load of 10,300,000 cfu/ac-day. This loading value was taken from the US EPA TMDL developed for the Cottonwood Creek watershed. (USEPA. 2000. Fecal Coliform TMDL Modeling Report: Cottonwood Creek Watershed, Idaho County, Idaho (Final Report 1/11/00). Washington, D.C.: Office of Water, USEPA). No load from wildlife calculated for BOR was added to this value. Wildlife loading is also applied to both rural and high-density residential land uses.

Chapter 3: Modeling Process for TMDL Development

EPA: Section 3.4.1, It seems as though for the existing conditions, the fecal coliform concentration from point sources is being zeroed out, and their permitted discharge concentration is being used for the allocation. However, later in the report it seems as though the allocation is being zeroed out too.

Response: The simulation process as it pertains to permitted dischargers was based on instructions from VA DEQ and was undertaken in the following manner. For the existing condition runs, the permitted point source dischargers were assumed to not discharge FC due to chlorination. For the allocation runs, the permitted dischargers were assumed to discharge their permitted values: a 200 cfu/mL concentration and their permitted flow rate.

EPA: Section 3.4.3, How was the storage time determined? Was it assumed that all wastes were stored for the maximum holding time or was it split into a percent being stored for the maximum storage, a percent for the maximum storage minus one day, and a percent for maximum minus two days, etc.?

Response: For the desired storage time, we calculated die-off in storage on a daily basis. For example, if manure was in storage for an average of 100 days, then manure entering storage on day 1 was assumed to undergo 99 days of die-off in storage. Manure entering storage on day 2 was assumed to undergo die-off for 98 days, and so forth with no die-off assumed for manure entering storage on day 100.

EPA: Section 3.4.3, Bullets three (Rural residential) and four (High-density residential) should both have wildlife loadings, as well.

Response: This is correct and the said bulleted statements will be modified in the report to include the loadings from wildlife.

EPA: Section 3.5.1, On page 55, the report states that "The overall quality of the regression between the flows at the two stations for the entire was good." Please elaborate on the word "entire".

Response: The word "entire" refers to the entire time period. The sentence should read "The overall quality of the regression between the flows at the two stations for the entire

time-period (10/1/1943 through 9/30/1960) was good." The sentence in the report will be modified.

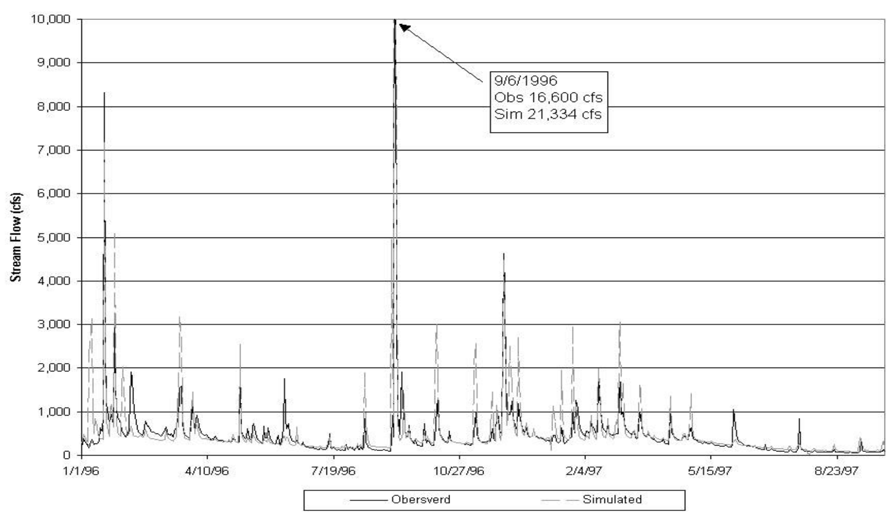
EPA: Section 3.5.1, On page 60, the report documents the breakdown of the flow components. Is this for both pervious and impervious land segments? Was the hydrograph checked as well? Was the simulated baseflow 65 or 66%?

Response: The flow-path breakdown is for the pervious segments only. The HSPF model does not simulate interflow or baseflow from impervious segments. The baseflow is 66% of the total flow.

EPA: Section 3.5.1, Can a figure documenting the simulated vs observed flow results from January of 1996 through September of 1997 be provided?

Response: Figure 1 is included as requested.

Figure 1.



Simulated and observed stream flow at Station 02061500 for portion of the validation period (September 1, 1996 to September 30, 1997)

EPA: Section 3.5.1, Can figures documenting the simulated flow for the other watersheds be provided as well?. Although there is no data to calibrate this data to, it would be helpful to visualize for which flow conditions the model is predicting elevated fecal coliform concentrations.

Response: Yes we will modify the figures (such as figure 4.5, 5.5, et.) that show the geometric mean of the FC concentration to include the flow data as well.

Chapter 4: TMDL for Sheep Creek Watershed

EPA: Section 4.1.4.1, Figure 4.2, Was the maximum concentration cap of the sampling method used in the 1970s 6,000 cfu/100mL?

Response: Yes, the data collected in the 1970s had a cap of 6,000 cfu/100 ml for fecal coliform.

EPA: Section 4.2.2.1, It was assumed that the fecal coliform contribution to the rural residential land use was cfu/day. Is there any removal of fecal coliform as the septic wastes migrates up through the soil profile?

Response: No reductions in FC concentration due to the effluent from a failing septic systems moving through the soil were considered. Because septic tanks retain influent for only 24 hours, we elected to assume that die-off in the septic tank was negligible and that the effluent immediately flowed to the surface where it contributed to the amount of fecal coliform available for transport by surface runoff (ACCUM). There is no general consensus as to how to simulate this and we chose to be conservative and assume that failing septic systems provide no-treatment. Furthermore, our sensitivity analysis revealed that septic contributions were negligible.

EPA: Section 4.3.2, The report states that the single permitted point source in the watershed was not considered significant because of the small flow rate. Was this discharge point considered in the allocation plan, because the waste load allocation is 0?

Response: This is a typographical error in the report. There were no permitted discharges in the Sheep Creek watershed. We will delete the sentence in Section 4.3.2 that refers to this permitted discharge in Sheep Creek.

EPA: Section 4.3.4, Table 4.13, Kindly document the constituent concentration for the AOQC and IOQC in cfu /100 mL as well.

Response: The concentration of FC in the interflow (IOQC) was 10 cfu/100mL and 5 cfu/100mL in groundwater (AOQC). The input parameters (IOQC and AOQC) and their values will be added to the input summary table for each watershed.

Chapter 5: TMDL for Elk Creek Watershed

EPA: Section 5.1.4.1, Figure 5.2, Is it possible to include the dates and fecal coliform concentrations of these sampling events in an appendix (for all watersheds)? Is it possible to determine the weather conditions when these samples were taken to get a rough idea of the flow regime?

Response: Table 2 is a sample of tables that we could include to help determine the hydrologic conditions of when the samples were collected. The table is for Elk Creek and lists the total rainfall for the six days up to and including the day the sample was collected (total precipitation for six days). If this table is satisfactory, we could include similar tables for all the watersheds in the report.

Table 2. Observed FC concentrations and antecedent rainfall for Elk Creek.

Station	Date	fcu/100ml	Total Rainfall for sampling day and preceding 5 days
4AECR003.02	8/19/92	300	0.08
4AECR003.02	9/21/93	2000	0.78
4AECR003.02	12/7/93	700	2.85
4AECR003.02	3/14/94	200	0.79
4AECR003.02	6/22/94	2500	0.00
4AECR003.02	9/13/94	100	0.00
4AECR003.02	12/13/94	300	0.55
4AECR003.02	3/22/95	600	0.07
4AECR003.02	6/14/95	4300	1.31
4AECR003.02	9/19/95	800	0.98
4AECR003.02	12/6/95	600	0.00
4AECR003.02	3/4/96	300	0.05
4AECR003.02	6/4/96	600	0.13
4AECR003.02	9/17/96	8000	1.53
4AECR003.02	12/16/96	200	1.11
4AECR003.02	3/26/97	600	0.28
4AECR003.02	6/23/97	1800	0.08
4AECR003.02	9/29/97	8000	0.00
4AECR003.02	12/15/97	100	0.29
4AECR003.02	3/30/98	300	0.00
4AECR003.02	6/11/98	700	0.44
4AECR003.02	9/16/98	200	0.00
4AECR003.02	12/2/98	300	0.00

EPA: Section 5.1.4.2, Does the simulated data accurately reflect the stream surface data from the March 2000 sampling?

Response: We could not run simulations for March 2000 because weather data for the period was not available when simulations were conducted. The rainfall data that we do have cover the period of 1/1/1980 through 9/30/1999. Furthermore, the sweep samples collected may not represent the conditions described in the modeling assumptions. Since we only had one rainfall station with a complete set of observations, we had to assume that rainfall occurred uniformly over the entire watershed. A storm occurred during the collection of the sweep samples and this storm moved from the top of the watershed to the outlet over the two days that the samples were collected. Comparison of the observed values from the sweeps may not agree with simulated results because of the assumption that the rainfall occurs uniformly over the entire watershed.

EPA: Section 5.2.2.1, Please reference the earlier discussion on how the Commonwealth determined the amount of septic systems and straight pipes. This comment can be applied to all of the TMDLs.

Response: In the chapter discussing each of the TMDLs we will include a cross-reference to section 2.6.2.1 in Chapter 2, which discuss how the number of failing septic systems and straight pipes were determined. The cross reference will be added to the opening paragraphs of section x.2.2.1 under the sub-headings of "Failing Septic Systems" and "Straight Pipes" for each chapter discussing the individual TMDL. For the subsections discussing failing septic systems, the opening paragraphs will be revised to say "Using the procedure outlined in Section 2.6.2.1 and based on an average household size of 2.5 persons and fecal coliform production of 1.95×10^9 cfu/day, a typical failing septic system contributes $\#.\#\# \times 10^{\#}$ cfu/day to the rural residential Land use. The numbers of failing septic systems in the subwatersheds of x watershed are shown in Table x.5." The subsection discussing straight pipes will be revised to say "A household with a straight pipe contributes 4.88×10^9 cfu/day (household size multiplied by daily fecal coliform production) directly into the stream. Using the procedure outlined in Section 2.6.2.1., the numbers of straight pipes in the subwatersheds of x watershed are given in Table x.5."

EPA: Section 5.2.2.3, In determining the amount of manure deposited by livestock to a stream, did the Commonwealth multiply the total livestock population by the average access to the stream or did they multiply the livestock for each subwatershed by the subwatershed's stream access?

Response: All livestock calculations were based on estimates of livestock in each subwatershed. For each subwatershed, an analysis was done based on the number of beef and dairy cattle, confinement schedules for each type of cattle, pasture areas with access to streams, etc., to determine the amount of time each type of cattle spent in the stream and the resulting fecal coliform load.

EPA: Section 5.3.4, Figure 5.3, One of the goals was to insure that the simulated data had a higher fecal coliform concentration than the observed data, when the sample concentration maxed out at 8,000 cfu/100 mL. Yet, in figure 5.3 four of the five simulated data points are less than or equal to the observed data when the observed data has hit its maximum concentration cap. Please explain why the Commonwealth is comfortable with this calibration.

Response: This comment is academic for several reasons. First, we are comparing daily average data (simulated) to instantaneous observations. One would expect that the simulated daily average concentrations would tend to be lower than the instantaneous observations collected during the day. In the real world, the largest fecal coliform source, fecal coliform loading by cattle, occurs almost exclusively during the day. Cattle avoid streams during low light conditions and night. Thus, monitoring only during the daylight hours would tend to pick up the peak concentrations and miss the lower nighttime concentrations (assuming that the concentrations are diurnal and related to the time of loading). The average daily fecal coliform concentrations that we used, averages out these high and low values and it is not unreasonable to expect them to be somewhat lower than instantaneous values. Secondly, we did not have observed flow data at the times the instantaneous samples were taken. Consequently, errors in flow that we have no way to assess may be responsible for large concentration discrepancies. For example, if we happened to over estimate flow on a particular day by 100%, our predicted concentrations would be reduced by 50%, even if our loadings, die-off, etc. were perfect. We felt that it was not wise to try to alter the simulated flow based on the observed FC concentration and it was also unwise to try to compensate for possible discrepancies in the simulated flow by over-adjusting water quality parameters. Lastly, if the simulated concentration was increased to greatly exceed the observed capped values, the problem mentioned in the comment on the feasibility of reducing NPS loads from the land surface greater than 50% would be exacerbated. Even if we have underestimated fecal coliform concentrations on 4 of 5 days with observations, we are requiring 100% reductions in direct cattle deposits, substantial reductions in uncontrollable wildlife contributions, 100% elimination of direct pipes from septic systems, and NPS reductions of over 50% that EPA questioned. We are comfortable with these calibrations given the limitations in the observed data used in the calibration process. We could alter the statement referred to in this comment to state "The second criterion was that the simulated concentrations be near or exceed the capped concentrations (8000 cfu/100ml) of the observed values." rather than "The second criterion was that the simulated concentrations equaled or exceeded the capped concentrations (8000 cfu/100ml) of the observed values."

EPA: Section 5.3.4, The report mentions that the wash-off factor was changed to 2.4 inches per hour, however, Table 5.14 shows a wash-off factor of 1.8 inches.

Response: The correct value for the wash-factor s 2.4. The value in Table 5.14 will be corrected.

EPA: Section 5.4.2, Seventy-five percent of the samples did not exceed the instantaneous standard of 1,000 cfu/100 mL. Several of the samples (based on figure 5.2) appear to show concentrations of fecal coliform below 200 cfu/100 mL. However, the model shows the geometric mean standard as being violated close to 100% of the time. Is the Commonwealth comfortable with this simulation, please elaborate?

Response: We are comfortable with the simulations. Referring to Figure 5.3, the simulated concentrations are close to or less than the lowest observed concentrations, while being close to or exceeding the highest observed concentrations. We considered this as a good indication that the simulations using the calibrated input data sufficiently represents the watershed processes controlling the transport of FC. It is impossible to determine 30-day geometric means from the observed data and we do not see any evidence that the observed data supports the contention that the lower range of the simulated 30-day geometric mean values are overestimated. There were only 23 observations over a five-year period. The variation in FC concentrations during the time between the collection of the samples is unknown except for the information provided by the model simulations. The time interval between samples heavily influences the calculation of the 30-day geometric mean.

Chapter 6; TMDL for machine Creek Watershed

EPA: Section 6.1.4.1, It should be mentioned that monitoring site 4AMCR004.60 is downstream of where Skinnels and Nininger Creek confluence with Machine Creek.

Response: The text will be rephrased to read: “Monitoring site 4AMCR004.60 is located on the impaired segment of Machine Creek, downstream of where Skinnels Creek and Nininger Creek confluence with Machine Creek (Figure 6.1).”

EPA: *Section 6.2.1, The draft TMDL states "The sole permitted point source in the Machine Creek watershed is the Body Camp Elementary School (VPDES Permit No. VA0020818) located on the southwestern boundary of the watershed (figure 2.3). The school is required to chlorinate and permitted to discharge fecal coliform at a rate of 200 cfu/100 mL." In the model was this facility treated as having a fecal coliform concentration of zero in the effluent?*

Response: The simulation process as it pertains to permitted dischargers was based on instructions from VA DEQ and undertaken in the following manner. For the existing condition runs, the permitted point source dischargers were assumed to not discharge FC due to chlorination. For the allocation runs, the permitted dischargers contributed a load that corresponded to their permit: 200 cfu/mL and the permitted flow rate.

EPA: *Section 6.2.3, The draft TMDL states "However, other factors such as precipitation and proximity to streams also impact the amount of fecal coliform from upland areas that reaches the stream." Die-off should also be mentioned.*

Response: The statement in the report will be modified to include die-off.

EPA: *Section 6.3.4, The report states that there are 12 quarterly samples for Machine Creek, however, there appear to be 13 samples in the Figure 6.2.*

Response: The report states that "The water quality component of HSPF was calibrated by comparing the simulated daily fecal coliform values with 12 quarterly Machine Creek fecal coliform samples collected between *1993 and 1996* at the VADEQ monitoring station 4AMCR004.60 located upstream of the confluence of Nininger Creek and Machine Creek. However, Figure 6.2 depicting exceedances, is based on the sampling period of *August 1992 to 1996.* The report can be rephrased to read: "The water quality component of HSPF was calibrated by comparing the simulated daily fecal coliform values with 12 quarterly Machine Creek fecal coliform samples collected between 1993 and 1996 at the VADEQ monitoring station 4AMCR004.60 located upstream of the confluence of Nininger Creek and Machine Creek. Although 13 water quality samples were taken between August 1992 and June 1996 (Figure 6.2) only the 12 samples falling within the calibration period were used".

EPA: *Section 6.3.4, Kindly verify the wash-off factor for Elk Creek.*

Response: The value of 2.4 was verified as being used in the simulations.

EPA: Section 6.3.4, Figure 6.3, One of the calibration goals was to insure that "the simulated concentrations equaled or exceeded the capped concentrations of the observed values." There is a gross disparity between the simulated concentration and the sole observed capped concentration value. Please elaborate on this calibration.

Response: The response to this comment is similar to the response to a comment on the calibration for Elk Creek. There are several reasons why we consider this calibration sufficient. First, we are comparing daily average data (simulated) to instantaneous observations. One would expect that the simulated daily average concentrations to not always be greater than the instantaneous observation due to the inherent variability of FC concentrations throughout the day. Secondly we did not have flow data for the subwatersheds and therefore were uncertain of the accuracy of the simulated flow. We felt that it was not wise to try to alter the simulated flow based on the observed FC concentration and it was also unwise to try to compensate for possible discrepancies in the simulated flow by over-adjusting water quality parameters. Finally, it is not a good idea to try to calibrate for one value and ignore the other 10 observations. As suggested earlier, we could alter the statement referred to in the comment to state, "The second criterion was that the simulated concentrations be near or exceed the observed capped concentrations (8000 cfu/100ml)." rather than "The second criterion was that the simulated concentrations equaled or exceeded the capped concentrations (8000 cfu/100ml) of the observed values."

EPA: Section 6.4.3, The report states that "Since a 100% reduction in direct deposition from cattle and a 60% reduction in direct deposits (scenario 5) did not achieve the TMDL goal, reductions were required from other sources." This statement makes it seem as though the Commonwealth first determines if reductions in cattle in-stream and wildlife will allow the water to attain standards and that only if these reductions do not work are alternatives investigated. Obviously, this is not the case, could this statement be reworded?

Response: This is not our approach. The intent of the simulations was to show that we also had to address the FC loads coming from the land surface. We will reword the sentence in the report to make the intended message clear.

Chapter 8: TMDL for Big Otter River Watershed

EPA: Section 8.4.3, Please elaborate on how unimpaired waters may be contributing to violations in the Big Otter River. Please illustrate that these waters were considered unimpaired based on the 1,000 cfu/ 100 mL standard and may in fact be violating the geometric mean of 200 cfu/100 mL.

Response: We will include a statement in the report such as a numerical example that demonstrates that the two standards assess the quality of the water differently. For instance, if the FC concentrations for a stream were at a constant 250 cfu/100 mL, the 1000 cfu/100 mL instantaneous standard would never be violated and the stream would not be listed as impaired. However, the waters from this stream would violate the 30-day geometric mean standard 100% of the time.

Additional comments from EPA via phone conversation with Mr. Gold on 10/11/00

EPA: How was the NPS loading from failing septic systems modeled?

Response: The fecal coliform loading from failing septic systems was applied uniformly to the rural or low-density residential land use classification land surface, where it would be subject to wash-off.

EPA: Could an appendix be added to the TMDL document that illustrates all of the point source's contributions to flow and fecal coliform loadings to each stream within the Big Otter River basin?

Response: Yes, this appendix will be incorporated into the document before final submission to EPA.

Please feel free to contact me at 804-371-0297 if you have any questions or comments.

Sincerely,

William Keeling
VA DCR

Cc: Mark Bennett, VA DCR
Charles Martin, VA DEQ
Thomas Henry, USEPA

November 1, 2000

Mr. Peter Gold
United States Environmental Protection Agency
Region III
1650 Arch Street
Philadelphia, Pennsylvania 19103-2029

Dear Mr. Gold:

The Virginia Department of Conservation and Recreation (VA DCR) appreciates the opportunity to append our responses to EPA's comments for the fecal Coliform TMDLs for Sheep Creek, Elk Creek, Machine Creek, Little Otter River, and the Lower Big Otter River. In this appended response EPA's comments have been restated in italics and then followed the comment(s) with the original response then the appended response for the particular comment(s).

EPA: *Section 2.6.3, If wildlife is considered as a loading to the commercial/industrial land use, it should be considered for the rural and high density residential land uses, as well.*

Response: The commercial/industrial land use is assigned a load of 10,300,000 cfu/ac-day. This loading value was taken from the US EPA TMDL developed for the Cottonwood Creek watershed. (USEPA. 2000. *Fecal Coliform TMDL Modeling Report: Cottonwood Creek Watershed, Idaho County, Idaho (Final Report 1/11/00).* Washington, D.C.: Office of Water, USEPA). No load from wildlife calculated for BOR was added to this value. Wildlife loading is also applied to both rural and high-density residential land uses.

Appended Response: The Commonwealth agrees that the language in the document should reflect that fecal coliform from wildlife are contributed to both the rural and high-density residential land uses. The TMDL document submitted to EPA will have this language included.

EPA: *Section 6.3.4, Figure 6.3, One of the calibration goals was to insure that "the simulated concentrations equaled or exceeded the capped concentrations of the observed values." There is a gross disparity between the simulated concentration and the sole observed capped concentration value. Please elaborate on this calibration.*

Response: The response to this comment is similar to the response to a comment on the calibration for Elk Creek. There are several reasons why we consider this calibration sufficient. First, we are comparing daily average data (simulated) to instantaneous observations. One would expect that the simulated daily average concentrations to not always be greater than the instantaneous observation due to the inherent variability of FC concentrations throughout the day. Secondly we did not have flow data for the subwatersheds and therefore were uncertain of the accuracy of the simulated flow. We felt that it was not wise to try to alter the simulated flow based on the observed FC concentration and it was also unwise to try to compensate for possible discrepancies in the simulated flow by over-adjusting water quality parameters. Finally, it is not a good idea to try to calibrate for one value and ignore the other 10 observations. As suggested earlier, we could alter the statement referred to in the comment to state, "The second criterion was that the simulated concentrations be near or exceed the observed capped concentrations (8000 cfu/100ml)." rather than "The second criterion was that the simulated concentrations equaled or exceeded the capped concentrations (8000 cfu/100ml) of the observed values."

Appended Response: The Commonwealth agrees that the language in the document should state, “The second criterion was that the simulated concentrations be near or exceed the observed capped concentrations (8000 cfu/100ml) if possible. However, since there were very few observed fecal coliform concentrations spread over the time period simulated it is possible that there could be significant discrepancies between the simulated and the observed fecal coliform concentration data”. Additionally, if model parameters were adjusted to capture the one capped observed value that is significantly above the simulated value (Figure 6.3) then the remaining observed points would most likely not fit the calibration curve as well as they currently do. Therefore, the Commonwealth considers this calibration sufficient.

Please feel free to contact me at 804-371-0297 if you have any questions or comments.

Sincerely,

William Keeling
VA DCR

CC: Mark Bennett, VA DCR
Charles Martin, VA DEQ
Thomas Henry, USEPA

Addendum to the Big Otter River Basin Fecal Coliform TMDLs (January 2001)

EPA's comments, as provided in their letter reviewing the fecal coliform TMDLs for five impaired segments in the Big Otter River basin, are re-stated in italics and followed by the particular response for each comment.

EPA: *Section 5.2.1, States that there are two point sources (Gunnoe Sausage Company and Otter River Elementary School) in the Elk Creek watershed. However, section 5.3.2 states that there is only one permitted point source. It is mentioned that neither of these facilities discharge to the impaired segment of Elk Creek. How many point sources are there within the Elk Creek watershed? How was their load allocated to the Big Otter? For the allocation were the point sources modeled as discharging at their permitted concentration?*

Response: There are two point sources for fecal coliform in the Elk Creek watershed: Gunnoe Sausage Company (VA0001449) and Otter River Elementary School (VA0020851). Neither of these contributed fecal coliform to the impaired segment on Elk Creek. Only the Gunnoe Sausage Company (VA0001449) was used in the simulations as a contributor to the impairment of the Lower Big Otter River. The Otter River Elementary School (VA0020851) was not used in the simulations for the Lower Big Otter River impairment because the design flow for this source was 0.0696 cfs, which was considered insignificant. The Gunnoe Sausage Company point source (VA0001449) was modeled as discharging fecal coliform at the permitted concentration for the allocation. Table 1 summarizes the flow and load information for Elk Creek. The point source load from Elk Creek was incorporated into the Lower Big Otter TMDL simulations as an upstream inflow. As modeled, the outflow from Elk Creek flows into Buffalo Creek, and the Buffalo Creek outflow is an inflow into the Lower Big Otter River.

Table 1. The hourly and annual loads from the point sources in the Elk Creek watershed.

PS Discharge	Flow (cfs)	Load (cfu/hr)	Annual Load[1] (cfu/yr)
VA0001449 [2]	0.6003	122,500,000	$1.07x10^{12}$
VA0020851 [2]	0.0696	14,200,000	$1.24x10^{11}$
Total			$\mathbf{1.19x10^{12}}$

[1] Annual load is hourly load times 8,760 hr/yr
[2] Does not contribute to impaired segment in Elk Creek HUP.

EPA: *Section 7.2.1, States that there are four permitted point sources in the Little Otter River watershed. However, in Section 7.3.2 it mentions that there are five permitted point sources, two of which were modeled for. Please verify the number of permitted point sources within this watershed. Was the Waste Load Allocation (WLA) set at a value that incorporates the permitted discharge of all of the permitted point sources? How was the loading from the facilities not modeled incorporated into the WLA and how was it determined that this additional loading would not affect the model? A WLA for each point source should be provided as an addendum to the report. A modeling run showing the effects of the non-modeled point sources should be provided with the addendum.*

Response: Section 7.3.2 is in error and should state there are four permitted point sources in the Little Otter River watershed. Section 7.2.1 is correct in regards to the number of permitted point sources in the Little Otter River watershed. However, only three of these point sources have limits for fecal coliform or the alternate disinfection clause in their permit and thus need WLAs for fecal coliform. Table 2 shows the point sources listed in table 7.5 of the TMDL document and the modified list for this addendum.

Table 2. List of permitted point sources in the Little Otter River watershed (L26b)

Name of Point Source		VPDES Permit No.	Comment
TMDL report:			
Thaxton Elementary School	Table 7.5	VA0020869	Listed but not modeled
Liberty High School	Table 7.5	VA0020796	Listed but not modeled
Dillons Trailer Park	Table 7.5	VA0087840	Listed but not modeled
City of Bedford STP	Table 7.5	VA0022390	Listed and modeled
City of Bedford WTP	Addendum	VA0001503	Modeled but not listed
Addendum:			
Thaxton Elementary School		VA0020869	Not included (no discharge to L26b)
Liberty High School		VA0020796	Included
Dillons Trailer Park		VA0087840	Included
City of Bedford STP		VA0022390	Included
City of Bedford WTP		VA0001503	Not included (no permit limit)

A comparison of annual loads using only those point sources given a WLA in the TMDL and using all point sources with a fecal coliform permit component is shown in table 3. While VA0001503 was given a WLA in the TMDL, that facility's permit is for flow, pH and TSS only, making a fecal coliform WLA unnecessary. The WLAs were calculated and modeled as if all the point sources were discharging fecal coliform at the permitted concentrations. As table 3 illustrates, there is no difference in the sum of wasteload allocations between the original point source simulation used in the TMDL and the simulation using all point sources with a fecal coliform permit component.

Table 3. The hourly and annual loads from the point sources in the Little Otter River watershed.

PS Discharge TMDL	**Flow (cfs)**	**Load (cfu/hr)**	**Annual Load[1] (cfu/yr)**
VA0001503	0.0680	13,900,000	1.22×10^{11}
VA0022390	3.0950	631,000,000	5.53×10^{12}
Total			**5.65×10^{12}**
PS Discharge Addendum			
VA0001503	0.0680	N/A[2]	N/A
VA0022390	3.0950	631,000,000	5.53×10^{12}
VA0020796	0.0378	7,800,000	6.83×10^{10}
VA0087840	0.0279	5,700,000	4.99×10^{10}
Total			**5.65×10^{12}**

[1] Annual load is hourly load times 8,760 hr/yr
[2] Permit is for flow, pH and TSS only (filter backwash at WTP)

Supporting this assessment is a modeling run using 200 cfu/100mL at design flow for all five point sources originally considered in the TMDL. Figure 1 shows a plot of the difference between the two modeling runs, indicating that the difference in terms of concentrations never exceeds 0.9 counts/100 mL. This increase did not result in any violations of the 30-day geometric mean standard with a 5% margin of safety, i.e. 190 cfu/100mL. Therefore, the Little Otter River TMDL accurately represents the point sources along this segment.

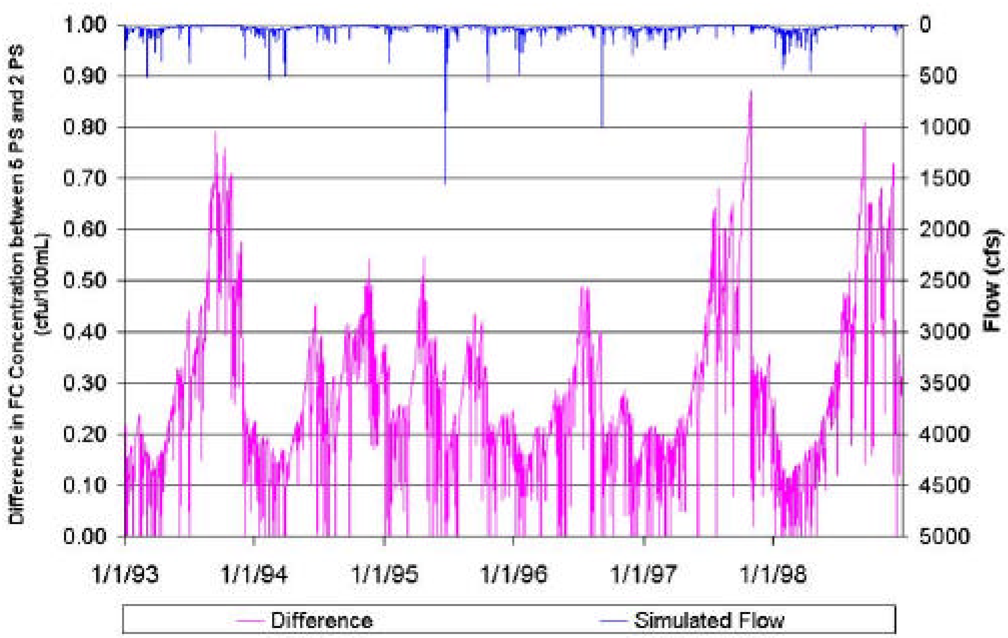


Figure 1. Difference in fecal coliform concentration for the modeling run with five point sources and the modeling run with only the original two point sources used in the simulations.

To reflect the above analysis, tables 1.17 and 7.22 need to be replaced with the following table 4. The WLA should read 5.65×10^{12} and not 6.8×10^{12}. It appears that in adding the original point source loads, the exponent for VA0001503 was misread as 12 instead of 11.

Table 4. Annual fecal coliform loadings (cfu/year) used for developing the fecal coliform TMDL for the Little Otter River watershed (L26b)

Subwatershed	S WLA	S LA[a]	MOS[b]	TMDL
Little Otter River	5.65×10^{12}	$1,377.7 \times 10^{12}$	72.8×10^{12}	$1,456.15 \times 10^{12}$

[a] with LA from Machine Creek inflow of 849.4×10^{12} cfu/year
[b] Five percent of TMDL

Tables 5-8 show summaries of flow and loading information for permitted dischargers along the Machine Creek, Buffalo Creek, Flat Creek and the Lower Big Otter River impaired segments.

Table 5. The hourly and annual loads from the point sources in the Machine Creek watershed.

PS Discharge	Flow (cfs)	Load (cfu/hr)	Annual Load[1] (cfu/yr)
VA0020818	0.0696	14,200,000	1.24×10^{11}
Total			**1.24×10^{11}**

[1] Annual load is hourly load times 8,760 hr/yr

Table 6. The hourly and annual loads from the point sources in the Buffalo Creek watershed.

PS Discharge	Flow (cfs)	Load (cfu/hr)	Annual Load[1] (cfu/yr)
VA0020826	0.0062	1,270,000	1.11×10^{10}
VA0078999	0.6173	126,000,000	1.10×10^{12}
VA0089311	0.0124	N/A[2]	N/A
Total			**1.11×10^{12}**

[1] Annual load is hourly load times 8,760 hr/yr
[2] Permitted to discharge pool water (pH, solids).

Table 7. The hourly and annual loads from the point sources in the Flat Creek watershed.

PS Discharge	Flow (cfs)	Load (cfu/hr)	Annual Load[1] (cfu/yr)
VA0031194	0.3713	75,800,000	6.64×10^{11}
VA0050628	3.2492	N/A[2]	N/A
Total			**6.64×10^{11}**

[1] Annual load is hourly load times 8,760 hr/yr
[2] Permitted to discharge quarry dewatering (pH, solids) only .

Table 8. The hourly and annual loads from the point sources in the Lower Big Otter watershed.

PS Discharge	Flow (cfs)	Load (cfu/hr)	Annual Load (cfu/yr)
VA0078646	0.04641	N/A[1]	N/A
Total			**N/A**

[1] Permit is for flow, pH and TSS only (filter backwash at WTP)

All waste load allocations (WLAs) were calculated based on each point source discharging fecal coliform at permitted limits. Future changes in the permit may require a re-examination of the TMDLs to see if there are any impacts on water quality.